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TAP-II

PHASE II FINAL REPORT [U].

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September 1977

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BUNKER
RAMO

ELECTRONIC SYSTEMS DIVISION
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TABLE OF CONTENTS

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Section 1

INTRODUCTION

1.1 SCOPE

(U) The results of Phase I of the TAP-II development were contained in two volumes, TAP-II Beamforming System Software Final Report, and TAP-II Processing System Final Report, Hardware Documentation.

(U) This report, a revised drawings package, and a revised set of program listings, together with the earlier reports, constitutes a complete description of TAP-II with all revisions to 30 August 1977.

~~(U)~~ Section 2 of this document presents a complete description of all operator procedures. Section 3 discusses hardware and software details for Time-Domain beamforming, an additional capability. Software flow diagrams for Time Domain Beamforming and TAP-II Tape Formats are presented in Appendix A.

1.2 SOFTWARE FEATURES

(U) The major software blocks for the TAP-II system are depicted in Figure 1.2-1. They are beamforming, calibration, and editing. At the highest level, all analyses are initiated through an executive routine which receives direction through an interactive question and answer interchange with the operator. All analyses return to this executive after completion to request further operator direction.

1.2.1 Beamforming

(U) The primary function of the system is beamforming and spectral analysis. The various computational techniques utilized by TAP-II result in an extremely versatile capability. A selection between three different time domain windows allows the operator to make on-line tradeoffs between spectral line bandwidths and rolloff characteristics.

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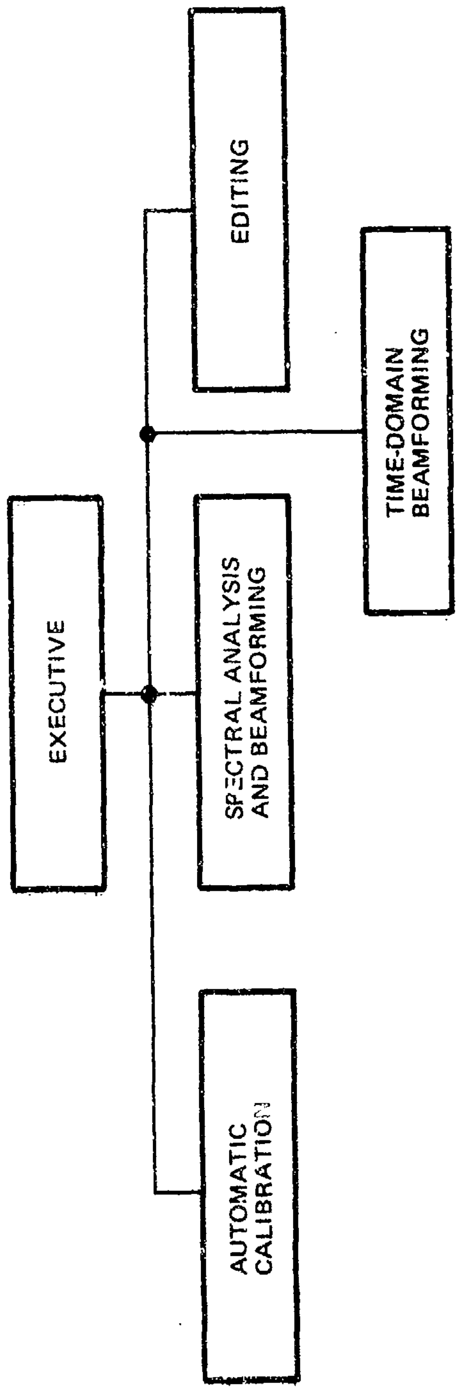

Figure 1.2-1. Software Organization

Three different stored element shading coefficient tables allow the effects of different array tapers to be investigated and also allow any combination of array elements to be zeroed out, effectively forming arrays with a reduced number of elements. Automatically generated calibration tables are used during the analysis to eleminate channel amplitude and phase tracking errors. Both simple and exponential data averaging are provided.

1.2.2 Calibration

(U) For the automatic calibration routine, a common signal is injected simultaneously into all array channels and Fourier techniques are used to compute normalized channel-to-channel gain and phase response variances.

1.2.3 On-Line Editing

(U) The editing feature allows seldom varied constants to be changed on-line by the operator if desired. Values changed in this manner include the date, three different 64-element shading coefficient tables, all plot format variables, element-element spacing for three different arrays, the speed of sound, and three prestored sample rates to be used for three different arrays.

1.2.4 Time-Domain Beamforming

(U) Up to 16 continuous analog broadband beams can be outputted.

1.3 COMMUNICATION INTERCHANGE

(U) As in TAP-I, a significant system feature is the method used for communication with the operator. All analyses are directed by an executive routine through a conversational question and answer interchange. As all questions are asked, the previously input answer is displayed in parentheses, and the operator can select this answer with

a simple carriage return. A rubout character instructs the computer to ignore the newly input answer (in case of input error), and to re-ask the question.

(U) Where logical, entire groups of questions can be skipped if no answers are to be changed. Answers to questions are immediately error-checked, and the question re-asked if an error is discovered.

1.4 SOFTWARE CONFIGURATION

(U) The TAP-II system is implemented on a Hewlett Packard 21MX computer, using the HP BCS operating system. The system is disc based, with the separate analysis programs residing on disc. The programs are loaded (as entire coreloads) as required. The system software falls into the following categories:

(1) FORTRAN Analysis Routines. All analysis routines and the executive are written in FORTRAN. Communication with the disc, input data source, and an external array processor is effected through FORTRAN calls.

(2) Assembly Language Disc and Interface Handling Routines. These routines, written in HP assembly language, handle all control of the disc and data input interfaces. They are FORTRAN-callable.

(3) Coreload Transfer Routines. Special software was developed to transfer program coreloads to and from disc. These routines, written in HP assembly language, are FORTRAN-callable.

(4) Array Processor Software. All actual computation is done in a Floating Point Systems AP120B array processor which is controlled by the 21MX computer. Most communication with the processor is handled through FORTRAN calls, using manufacturer-supplied routines. In time domain beamforming, special AP microcoded routines are used.

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Section 2

OPERATING INSTRUCTIONS

2.1 INTRODUCTION

(U) Operation of the TAP-II System is through the CRT keyboard and the sense switches on the 21MX front panel.

2.1.1 Conventions

(U) Certain conventions apply to all keyboard entries, as follows:

(1) For numeric inputs, a permissible range is usually printed within parentheses: (0-100). Any value outside this range will result in a repeated request to enter the number. The same will occur if an illegal character is entered.

(2) For numeric inputs, the current value is also printed within parentheses. This value will remain unchanged if RETURN is pressed (no characters entered).

(3) All numeric inputs are integers (i.e., no fractional part) unless a decimal point appears in the range of current value printouts. For integers, the decimal point must be omitted; for other numbers, the decimal point may be omitted if there is no fractional part (tenths, hundredths, etc.).

(4) For all numeric inputs, leading zeros, trailing zeros, and the sign, if positive, may be omitted.

(5) All inputs are completed by pressing RETURN. The use of the RETURN key is assumed and will not be repeated in the operating instructions.

(6) An error recognized before pressing RETURN may be corrected by pressing RUBOUT, then making the proper entry.

(7) Entering 12345 in place of most numeric inputs will result in control being returned to the Executive.

2.1.2 System Hardware

(U) A block diagram of the TAP-II computer system is given in Figure 2.1-1. Turn-on and operation of the HP-21MX computer and the High-Density Digital Recorder are described elsewhere. Table 2.1-1 is an operator checklist describing the normal switch settings for the remaining components of the system. The switches should be set to the recommended positions prior to attempting a beamforming operation.

(U) Table 2.2-2 gives the computer and computer I/O extender card slot assignments. All I/O cards must be in place, except for the punch, which is optional. A blank slot must be before the last card, which is the AP-120B interface.

(U) The system cabling diagram is shown in Figure 2.1-2. Figure 2.1-3 shows a detail of the digital controller rear panel.

2.2 EXECUTIVE

(U) The Executive is the starting point for all programs and functions. After completion of any function, control is automatically returned to the Executive. However, when the computer or other components of the system have been turned off, it is necessary to "BOOT" the system as follows:

(1) Ensure that power is on at all applicable units (Computer, I/O Extender, CRT Terminal, Line Printer, Digital Controller, AP-120B). Ensure that TAP-II System disc is loaded and DISC READY is illuminated.

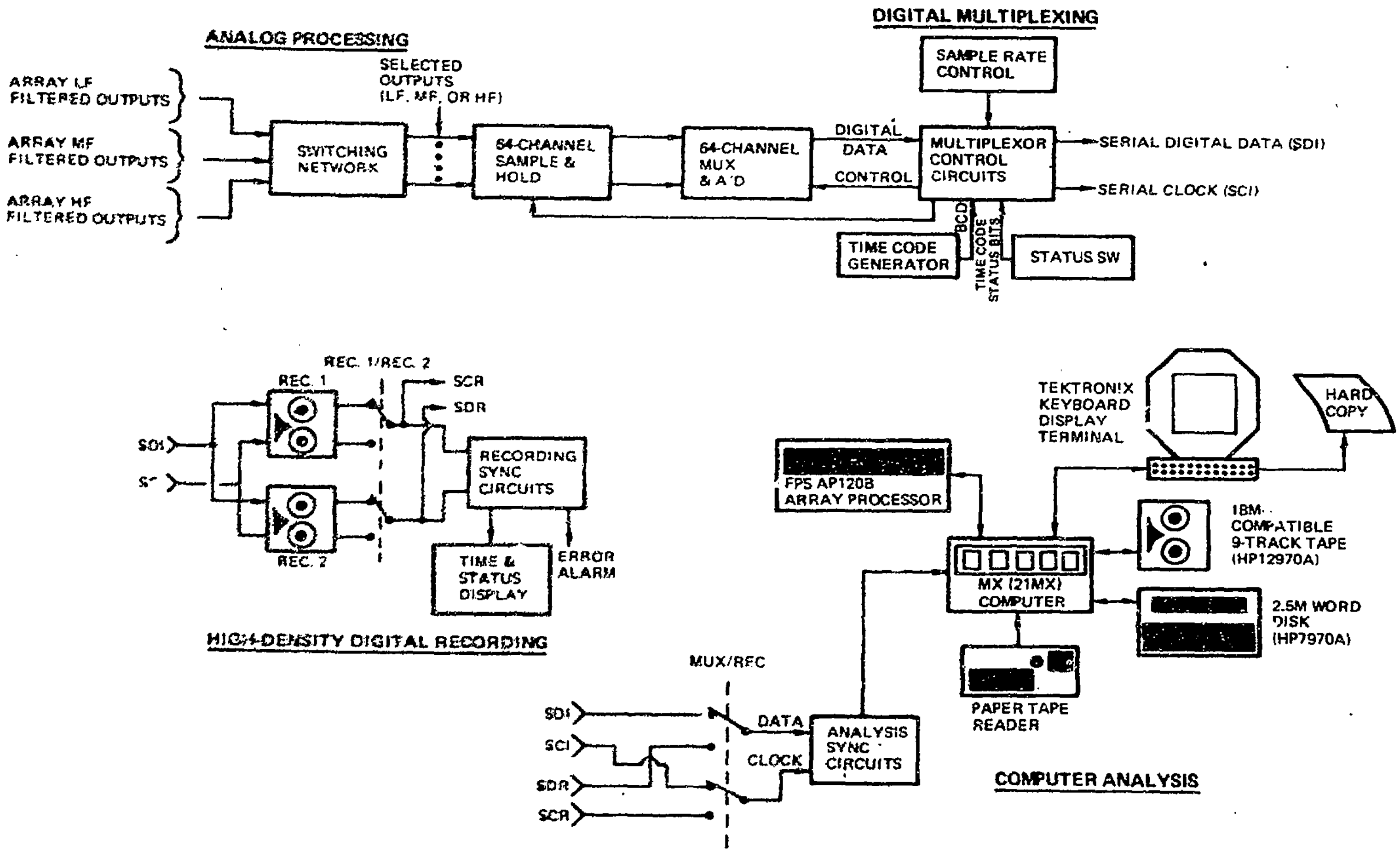

Figure 2.1-1. Hardware Block Diagram

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TABLE 2.1-1

Equipment Check List

1. Sample and Hold Assembly (rack 12)

   a. Power switch - ON

   b. Hold/not hold - HOLD position

2. Status Panel (rack 12)

   a. Display - ON

   b. Status toggle switches - The 12 toggle switches may be used to identify blocks of data on the HDDR magnetic tape. The indicators above the toggle switches show the status bit configuration from the data currently appearing on the HDDR transport read lines.

   c. Time display - The time display on the status panel displays the time field from the data currently appearing on the HDDR transport read lines.

3. Digital Controller (rack 12)

   a. Run/stop switches - set to RUN

   b. Input Select - MUX and On-line.

   c. Alarm switch - set to ON. Internal circuitry will activate the alarm if a fault is detected in the serial digital data currently appearing on the HDDR transport read lines.

4. A/D Converter (rack 12)

   a. Power switch - ON

   b. Last channel - set to 77

5. Counter/Timer (rack 12)

   The Counter/Timer is primarily used to monitor the hydrophone sample rate. When used for this purpose, set up as shown below.

   a. Power switch - ON

   b. Storage - OFF

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TABLE 2.1-1 (Continued)

c. Clock - Internal

d. FREQ/TIME/MULT - Hz/s/10^6

e. Function - Freq A

f. Input A - Multiplexer FP (red) and ground (black) on the Digital Controller

g. A Sync - adjust as necessary

6. Clock (rack 12)

a. Power - ON

b. Set to correct time

7. Sample Rate Clock (rack 12)

The basic timing source for controlling sample rate is the HP-3320 Frequency Synthesizer.

Frequency Synthesizer - Power ON, signal level to +26 dB, frequency dial as directed in Beamforming INPUT NEW PARAMETER prompt (see Figure 2.4-2)

8. Power Supply (rack 12)

a. Power - ON

b. Voltages - adjust to level specified on labels

9. AC Regulator (rack 12)

a. Power - ON

b. Meter - nominal 118 VAC

10. AP-120B (rack 13)

a. Power - ON

b. +5V indicator ON

c. +12V indicator ON

d. -5V indicator ON

TABLE 2.1-1 (Continued)

11. D/A Converters (rack 13) a. Mode switches - random and remote b. Last channel - 10 c. Power - ON d. Other toggle switches - any position

TABLE 2.2-2

21MX Computer I/O Slot Assignments

I/O Slot	Interface Card Type	Location
10	12665 Serial Interface	CPU
11	TAP-II Digital Controller	CPU
12	Disc Interface 1	CPU
13	Disc Interface 2	CPU
14	Mag Tape Interface 1	CPU
15	Mag Tape Interface 2	CPU
16	High-Speed Terminal	CPU
-	I/O Extender	CPU
17	Line Printer	Extender
20	Time Base Generator	Extender
21	8 Bit Duplex Register (PTR)	Extender
22	8 Bit Duplex Register (PTP)	Extender
23	TAP-II A/D Converter	Extender
24	BLANK	Extender
25	AP-120B Processor	Extender

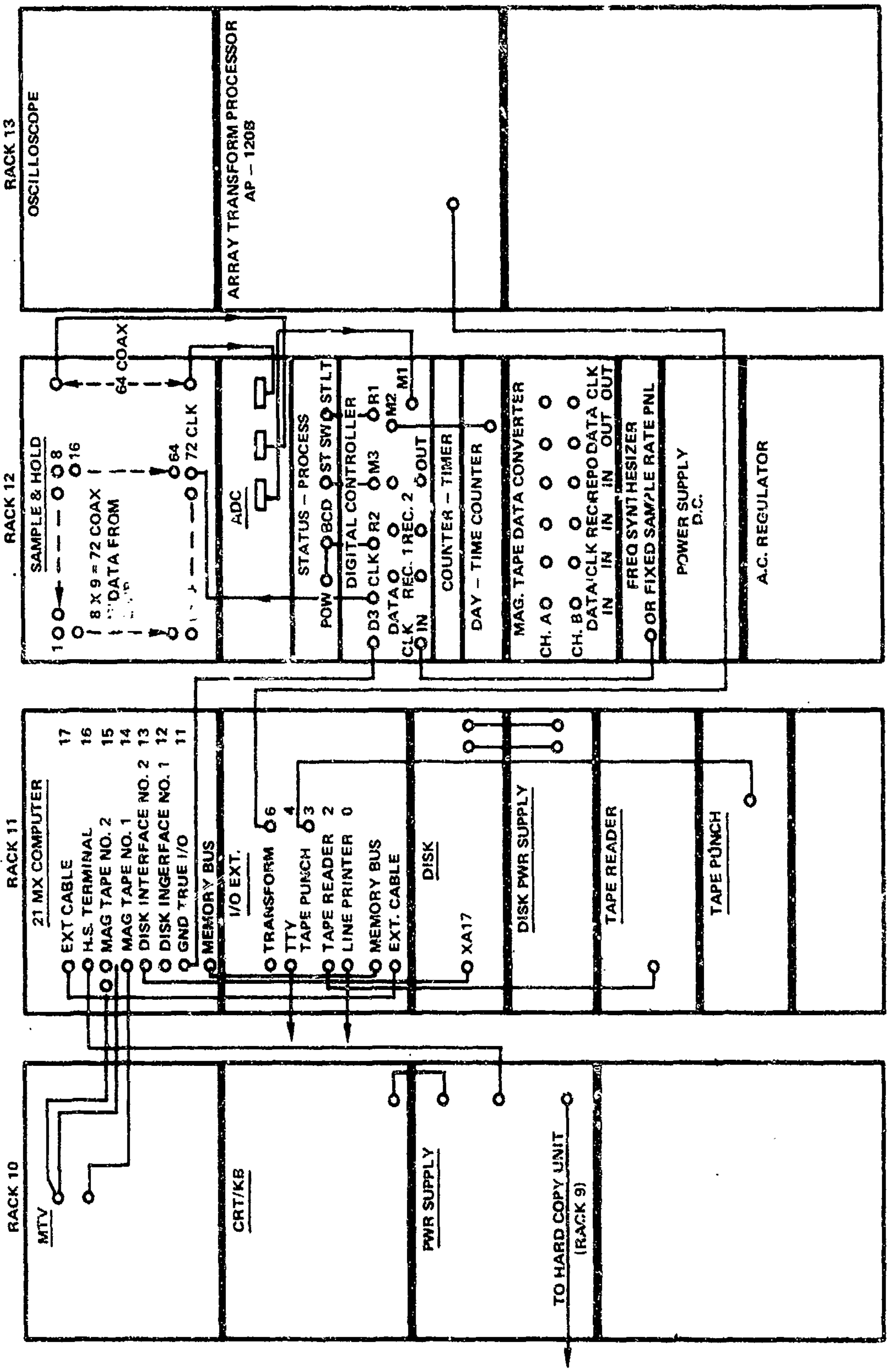
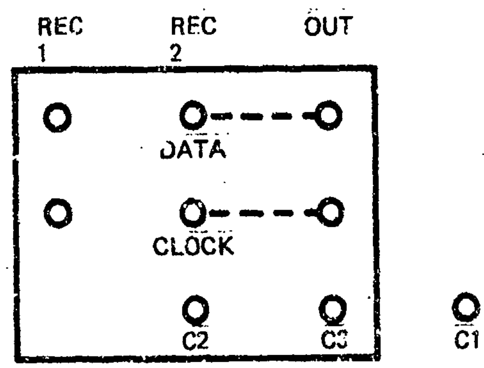


Figure 2.1-2. System Cable Diagram



C1 = Clock Input (from frequency synthesizer)

C2 = S&H Strobe (to NUC S&H)

C3 = Interrupt to CPU (to D/A Computer Interface)

NOTE: Data and clock outputs must be jumpered to Rec 2 data and clock inputs, respectively. These outputs may be cabled in parallel to the HD102 ADDR encoder, if desired. Rec 1 data and clock inputs are alternate inputs to be used when the Leach recorder is in operation.

Figure 2.1-3. Detail of Digital Controller Rear Panel BNC Connections

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(2) At the computer, set the S register to 041201 and press STORE.

(3) At the computer, press PRESET, IBL, RUN, RUN. The system should be loaded from the disc and the following message should be displayed:

TAP-II EXECUTIVE

ENTER OPERATION TO BE PERFORMED:

B = BEAMFORMING

C = CALIBRATION

E = EDITING

L = DISPLAY STORED DATA

T = TIME DOMAIN BEAMFORMING

This message will be displayed at the completion of any of the listed functions.

To start any of these functions, enter the indicated letter.

2.3 CALIBRATION ANALYSIS

(U) The calibration analysis routine is used to normalize channel-to-channel gain and phase response variances. Execution of the array calibration analysis is required prior to attempting beamforming. The calibration analysis should be repeated whenever a change in the characteristics of the array may have taken place.

(U) The calibration mode is called by entering a C when in the Executive routine. The options listed below are displayed on the CRT when the calibration routine is entered:

1 = BEAMFORMER CALIBRATION

2 = NOISE ANALYSIS

3 = FORCE CAL TABLE TO UNITY

4 = DISPLAY CAL TABLE

(U) The operator should select the option appropriate for the activity desired. Selection of BEAMFORMER CALIBRATION results in alteration of the calibration tables used to normalize channel amplitude and phase information during beamforming. It also prints the absolute and/or normalized array channel responses at four frequencies within the array bandwidth. Selection of NOISE ANALYSIS allows the operator to obtain the calibration analysis line printer tabulation without altering the internal beamforming calibration tables. The FORCE CAL TABLE TO UNITY option sets the normalization factors for each channel to unity which results in the signal from each array channel being accepted by the beamforming analysis program without correction. DISPLAY CAL TABLE will display the current contents of any calibration table.

2.3.1 Beamformer Calibration

(U) This mode updates calibration tables for the array selected. Hydrophone channel calibration mathematically eliminates channel-to-channel variations in the analog signal path. The recommended procedure for calibration is to inject a white noise signal at the input point common to the array preamplifiers and to run the BEAMFORMER CALIBRATION program once for each array. The white noise should be band-limited before injection at the highest frequency capability of the array being calibrated or limited by the array filters, to prevent aliasing errors. The injected signal amplitude should be such that a 3-to 5-volt peak signal is applied to the A/D converter.

(U) To exercise the BEAMFORMER CALIBRATION from the EXECUTIVE program, type C. See Figure 2.3-1 for a typical calibration analysis input display. Select BEAMFORMER CALIBRATION by typing 1. The operator should respond to the prompts displayed to select the variables described below:

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```
     ***** TAP-II CALIBRATION ANALYSIS *****
     2Ø:12:19                    3 SEP 77

ENTER CAL TYPE:
                    1 = BEAMFORMER CALIBRATION
                    2 = NOISE ANALYSIS
                    3 = FORCE CAL TABLE TO UNITY
                    4 = DISPLAY CAL TABLE
(    Ø)
1
 ARRAY TYPE: (1=LF, 2=MF, 3=HF)
(    1)
2
 CAL TABLE NO: (1 - 2)
(    1)
 SAMPLE RATE (HZ). (2Ø.ØØ - 1ØØØ.ØØ)
(    79.98Ø)
128
 SET FREQUENCY SYNTHESIZER TO   219.648 KHZ.
 REFERENCE CHANNEL NO.: (1-64)
(    1)
32
 NUMBER OF AVERAGING INTERVALS: (1-128)
(   64)
 TYPE OF WEIGHTING WINDOW: (1=RECT, 2=HANNING, 3=RECT.)
(    2)
 TYPE OF OUTPUT (Ø=PARTIAL, 1=FULL):
(    Ø)
```

Figure 2.3-1

NUMBER OF AVERAGING INTERVALS

TYPE OF WEIGHTING WINDOW

TYPE OF OUTPUT

2.3.1.1 (C) ARRAY TYPE selection allows a new calibration table to be generated for either the low frequency, medium frequency or high frequency array, with a 1, 2, or 3 selection, respectively.

2.3.1.2 (U) The CAL TABLE No. may be 1 or 2. This allows up to two calibration tables to be stored simultaneously; usually done when two different filter sets (and/or sample rates) are to be used for the same array.

2.3.1.3 (U) SAMPLE RATE (Hz) must be set to the same value desired when the calibration table is used for beamforming. The frequency synthesizer must be set to a frequency 1716 times the desired sample rate, in Hz. For recommended sample rate values, see Beamforming (Sections 2.4.1.2 and 2.4.1.3).

2.3.1.4 (U) The REFERENCE CHANNEL No. selection is chosen from any channel known to be normal. Channel 32 is recommended for the reference channel.

2.3.1.5 (U) Increasing NUMBER OF AVERAGING INTERVALS removes the influence of sample-to-sample variations. For calibration on noise, 64 averages are recommended. Ten averages is sufficient for sine wave inputs.

2.3.1.6 (U) The TYPE OF WEIGHTING WINDOW is selected according to the characteristics desired. Normally, Hanning is selected.

2.3.1.7 (U) The TYPE OF OUTPUT may be either full or partial. The full printout prints both the absolute and relative response of each channel at 16 frequencies appropriate for the array chosen. The

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partial printout eliminates the absolute response lines, giving only the response relative to the reference channel in amplitude (decibels) and phase (degrees) at four frequencies. See Figure 2.3-2 for a typical partial output.

(U) To ensure that a good calibration has been obtained, the absolute levels printed for the reference channel should be in excess of -30 db in every frequency cell.

(U) The CALIBRATION ANALYSIS mode exits to the Executive Program upon completion.

2.3.2 Noise Analysis

(U) The NOISE ANALYSIS mode of the calibration routine allows the operator to determine the response of each hydrophone channel to the present input signal without altering the calibration table. A partial or full tabular output may be obtained on the line printer. Examination of the printout will reveal the amplitude response of each channel at frequencies which are appropriate for the array type selected. The NOISE ANALYSIS mode may be used by the operator for testing purposes when a calibration table which is known to be valid is stored in the computer and should not be disturbed. Except for the calibration table storage, the results of the NOISE ANALYSIS mode are identical to the BEAMFORMER CALIBRATION mode. This mode exits to the Executive program upon completion.

(U) Phase response is not analyzed for a NOISE ANALYSIS, and this parameter is set to zero on printout.

(U) See Figure 2.3-3 for a typical NOISE ANALYSIS input sequence, and Figure 2.3-4 for typical outputs.

2.3.3 Force Calibration Table to Unity

(U) This mode of operation eliminates the effect of calibration corrections for the array selected when the array is used in beamforming

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AUTCMATIC CALIBRATION 3-SEP-77 20:13:30 PAGE 1

ARRAY TYPE	= 2	BLOCK SIZE	= 32
REF. CHANNEL	= 32	DELTA-F	= 4.00
SAMPLE RATE	= 128.0	NO. AVERAGES	= 64
		WINDOW TYPE	= 2

		F =	12.0	F =	24.0	F =	36.0	F =	48.0
CH	T*	AMPL.	ANGLE	AMPL	ANGLE	AMPL.	ANGLE	AMPL.	ANGLE
1	R	-.0	-.2	-.0	.4	-.1	.8	-.1	1.9
2	R	.0	1.3	-.1	1.6	-.1	2.2	-.3	6.2
3	R	1.2	.4	1.1	.0	1.0	-1.2	.0	-.5
4	R	.1	1.5	.2	1.0	.1	1.3	-.1	6.7
5	R	-.5	4.3	-.4	2.3	-.4	1.0	-.2	2.3
6	R	.4	.8	.3	-.0	.2	-.4	-.2	-.3
7	R	-.7	1.8	-.7	1.2	-.6	1.0	-.3	1.0
8	R	-.8	.2	-.8	.7	-.8	1.6	-.2	3.7
9	R	.8	1.7	.7	.7	.5	.8	-.0	5.5
10	R	-.2	2.6	-.1	1.3	-.2	.8	-.3	4.5
11	R	-.6	1.7	-.6	1.4	-.5	1.3	-.2	2.8
12	R	-.4	2.9	-.3	1.5	-.5	2.0	-.2	8.5
13	R	.2	2.0	.3	1.6	.1	2.4	-.1	9.6
14	R	-.1	1.6	-.0	.9	-.1	-.0	-.2	1.2
15	R	-.5	.6	-.4	.1	-.4	.2	-.1	.8
16	R	.6	1.4	.6	.5	.3	.6	-.1	5.9
17	R	-.6	-.4	-.6	-.4	-.7	-1.0	-.3	1.3
18	R	.3	.4	.2	.2	-.0	.7	-.1	5.7
19	R	-.5	2.2	-.5	.8	-.7	1.1	-.2	2.5
20	R	-.1	-.0	-.1	.5	-.1	1.0	-.0	1.6
21	R	.1	.6	.1	.6	.1	.7	-.1	4.1
22	R	.2	1.2	.1	.2	-.1	.2	-.2	3.9
23	R	-.2	1.3	-.2	.9	-.2	.7	-.1	-1.1
24	R	-.0	2.1	.0	.7	-.1	-.3	-.2	2.0
25	R	-1.0	3.0	-1.0	1.4	-1.0	1.1	-.2	1.0
26	R	.3	1.8	.3	.3	-.2	-.9	-.2	.9
27	R	-.7	3.8	-.6	2.3	-.6	2.6	-.2	7.1
28		-.5	1.0	-.5	.7	-.6	1.2	-.3	6.6
29	R	-.1	-1.0	-.1	-.6	-.2	-.3	-.2	3.0
30	R	-.2	2.4	-.2	1.7	-.2	2.0	.1	3.6
31	R	-.8	.5	-.8	.2	-.8	.4	-.2	.7
32	R	-.0	.0	-.0	.0	-.0	.0	-.0	.0

* TYPE: R = RELATIVE A = ABSOLUTE.

Figure 2.3-2

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AUTOMATIC CALIBRATION 3 SEP 77 20:13:30 PAGE 2

ARRAY TYPE	= 2	BLOCK SIZE	= 32
REF. CHANNEL	= 32	DELTA-F	= 4.00
SAMPLE RATE	= 128.0	NO. AVERAGES	= 64
		WINDOW TYPE	= 2

		F =	12.0	F =	24.0	F =	36.0	F =	48.0
CH	T*	AMPL.	ANGLE	AMPL.	ANGLE	AMPL.	ANGLE	AMPL	ANGLE
33	R	.7	1.8	.8	1.1	.8	.2	.2	.3
34	R	-.2	2.0	-.2	1.1	-.1	.1	-.1	-.5
35	R	.3	2.0	.4	1.0	.4	.6	.2	.2
36	R	-.2	-.4	-.2	-.2	-.3	.1	-.2	2.2
37	R	.3	4.3	.4	2.1	-.3	2.1	-.0	7.5
38	R	.4	-.3	.4	.0	.3	.2	.0	2.9
39	R	-.6	-.1	-.5	.4	-.5	.5	-.1	1.7
40	R	-1.6	4.8	-1.3	2.8	-1.2	3.3	-.2	5.3
41	R	.9	2.0	.9	1.4	.8	1.4	.1	6.6
42	R	.1	1.6	.1	.0	-.1	-.4	-.2	2.3
43	R	-.4	5.2	-.2	2.4	-.2	1.2	-.1	2.4
44	R	.1	1.1	.2	.5	.2	-.4	-.1	-.3
45	R	-1.0	1.7	-.9	.6	-.8	.6	-.1	.7
46	R	-.7	4.0	-.5	2.1	-.4	1.0	-.1	-.6
47	R	.3	1.0	.3	.2	.1	-.1	-.2	4.1
48	R	.3	1.2	.4	.1	.3	-1.0	.0	- [illegible]
49	R	.2	2.2	.3	1.4	.3	1.2	-.0	[illegible]
50	R	-.0	2.1	.0	1.3	-.0	1.8	.0	3 [illegible]
5.		.2	-.4	.2	-1.9	.0	-2.3	-.1	7.2
52	R	.5	-.1	.5	-.3	.3	.2	-.1	7.1
53	R	-.2	3.3	-.0	1.7	-.2	1.8	-.2	8.7
54	R	-.2	1.2	-.2	1.1	-.2	1.4	-.1	5.5
55	R	.3	2.7	.3	1.1	.2	1.2	.0	6.6
56	R	-.6	2.0	-.6	1.6	-.6	2.5	-.2	6.3
57	R	-.8	1.0	-.7	.4	[illegible]	.4	-.3	1.2
58	R	-.3	.7	-.3	.5	-.3	.8	.1	-.8
59	R	-.1	4.5	.1	2.2	.2	1.1	.0	1.4
60	R	-.1	1.2	-.1	.6	-.2	.8	-.2	4.0
61	R	.0	.4	.0	-.0	-.1	-.1	-.1	3.7
62	R	.5	1.9	.6	.7	.6	-.4	.2	-1.3
63	R	-.5	.3	-.5	.4	-.6	1.5	-.3	5.2
64	R	3.2	-7.6	-1.7	-4.7	-.5	-17.2	4.3	8.0
32	A	-29.8	.0	-29.8	.0	-29.9	.0	-30.0	.0

Figure 2.3-2 (Continued)

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```
     ***** TAP-II CALIBRATION ANALYSIS *****
     20:27:11                      3 SEP 77

ENTER CAL TYPE:
                    1 = BEAMFORMER CALIBRATION
                    2 = NOISE ANALYSIS
                    3 = FORCE CAL TABLE TO UNITY
                    4 = DISPLAY CAL TABLE
(    Ø)
2
 ARRAY TYPE: (1=LF, 2=MF, 3=HF)
(    2)
 SAMPLE RATE (HZ): (2Ø.ØØ - 1ØØØ.ØØ)
(   128.ØØØ)
 SET FREQUENCY SYNTHESIZER TO   219.648 KHZ.
 REFERENCE CHANNEL NO.: (1-64)
(   32)
 NUMBER OF AVERAGING INTERVALS: (1-128)
(   64)
 TYPE OF WEIGHTING WINDOW: (1=RECT, 2=HANNING, 3=RECT.)
(    2)
 TYPE OF OUTPUT (Ø=PARTIAL, 1=FULL):
(    Ø)
```

Figure 2.3-3

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AUTOMATIC CALIBRATION 3 SEP 77 20.27:18 PAGE 1

		BLOCK SIZE	= 32
ARRAY TYPE	= 2	DELTA-F	= 4.00
REF. CHANNEL	= 32	NO. AVERAGES	= 64
SAMPLE RATE	= 128.0	WINDOW TYPE	= 2

		F = 12.0		F = 24.0		F = 36.0		F = 48.0	
CH	T*	AMPL.	ANGLE	AMPL.	ANGLE	AMPL.	ANGLE	AMPL.	ANGLE
1	R	.0	.0	-.1	.0	-.1	.0	-.1	.0
2	R	.0	.0	-.1	.0	-.2	.0	-.2	.0
3	R	1.1	.0	1.1	.0	1.0	.0	.0	.0
4	R	.1	.0	.1	.0	.1	.0	-.1	.0
5	R	-.5	.0	-.4	.0	-.4	.0	-.2	.0
6	R	.4	.0	.3	.0	.2	.0	-.2	.0
7	R	-.7	.0	-.7	.0	-.6	.0	-.3	.0
8	R	-.8	.0	-.8	.0	-.8	.0	-.2	.0
9	R	.8	.0	.7	.0	.5	.0	-.0	.0
10	R	-.2	.0	-.2	.0	-.2	.0	-.3	.0
11	R	-.6	.0	-.6	.0	-.5	.0	-.2	.0
12	R	-.4	.0	-.3	.0	-.3	.0	-.1	.0
13	R	.3	.0	.3	.0	.2	.0	-.1	.0
14	R	.0	.0	.0	.0	.1	.0	.2	.0
15	R	-.5	.0	-.4	.0	-.4	.0	-.1	.0
16	R	.7	.0	.6	.0	.3	.0	-.1	.0
17	R	[illegible]	.0	-.6	.0	.6	.0	-.3	.0
18	R	.4	.0	.2	.0	-.0	.0	-.1	.0
19	R	-.5	.0	-.5	.0	-.6	.0	-.2	.0
20	R	.0	.0	-.1	.0	.1	.0	.0	.0
21	R	.1	.0	.1	.0	.1	.0	-.1	.0
22	R	.2	.0	.1	.0	-.0	.0	-.2	.0
23	R	-.2	.0	-.2	.0	.1	.0	-.1	.0
24	R	.0	.0	.0	.0	-.1	.0	-.2	.0
25	R	-1.1	.0	-.9	.0	-.9	.0	-.2	.0
26	R	.3	.0	.3	.0	.2	.0	.1	.0
27	R	-.7	.0	-.6	.0	-.7	.0	- 2	.0
28	R	-.5	.0	-.5	.0	-.5	.0	- 2	.0
29	R	-.1	.0	-.1	.0	.2	.0	-.2	.0
30	R	-.2	.0	-.2	.0	-.2	.0	.0	.0
31	R	-.8	.0	-.8	.0	-.8	.0	- 2	.0
32	R	.0	.0	.0	.0	.0	.0	.0	.0

* TYPE: R = RELATIVE A = ABSOLUTE.

Figure 2.3-4

BUNKER RAMO

AUTOMATIC CALIBRATION 3 SEP 77 20:27:18 PAGE 2

ARRAY TYPE = 2
REF. CHANNEL = 32
SAMPLE RATE = 128.0

BLOCK SIZE = 32
DELTA-F = 4.00
NO. AVERAGES = 64
WINDOW TYPE = 2

		F = 12.0		F = 24.0		F = 36.0		F = 48.0	
CH	T*	AMPL.	ANGLE	AMPL.	ANGLE	AMPL.	ANGLE	AMPL.	ANGLE
33	R	.7	.0	.8	.0	.8	.0	.2	.0
34	R	-.2	.0	-.2	.0	-.1	.0	-.1	.0
35	R	.7	.0	.3	.0	.4	.0	.2	.0
36	R	-.2	.0	-.2	.0	-.2	.0	-.2	.0
37	R	.4	.0	.4	.0	.3	.0	-.0	.0
38	R	.4	.0	.3	.0	.3	.0	.0	.0
39	R	-.5	.0	-.3	.0	-.5	.0	-.1	.0
40	R	-1.3	.0	-1.3	.0	-1.2	.0	-.3	.0
41	R	1.0	.0	.9	.0	.8	.0	.1	.0
42	R	.1	.0	.1	.0	-.1	.0	-.2	.0
43	R	.4	.0	.2	.0	.2	.0	-.1	.0
44	R	.1	.0	.2	.0	.2	.0	-.1	.0
45	R	-1.0	.0	-.9	.0	-.8	.0	-.1	.0
46	R	-.6	.0	-.6	.0	-.4	.0	-.1	.0
47	R	.4	.0	.3	.0	.1	.0	-.2	.0
48	R	.3	0	.4	.0	.4	.0	0	.0
49	R	.2	.0	.3	.0	.2	.0	-.0	.0
50	R	.0	.0	.0	.0	-.0	.0	.0	.0
51	R	.2	.0	.2	.0	.0	.0	-.1	.0
52	R	.6	.0	.5	.0	.3	.0	.1	.0
53	R	-.1	0	-.0	.0	-.2	.0	-.1	.0
54	R	-.2	0	-.2	.0	-.2	.0	-.1	.0
55	R	.3	.0	.3	.0	.2	.0	-.0	.0
56	R	-.6	.0	-.6	.0	-.6	.0	-.2	.0
57	R	-.8	.0	-.7	.0	-.7	.0	-.2	.0
58	R	.3	.0	.3	.0	.3	.0	.1	.0
59	R	-.1	.0	.1	.0	.2	.0	0	.0
60	R	-.1	0	-.1	.0	-.2	.0	-.2	.0
61	R	.0	.0	-.0	.0	-.0	.0	-.1	.0
62	R	.3	0	.5	.0	.6	.0	.2	.0
63	R	-.5	0	-.6	.0	-.4	.0	-.2	.0
64	R	14.3	.0	13.0	.0	14.4	.0	16.1	.0
32	R	-30.0	.0	-29.8	.0	-29.8	.0	-30.3	.0

Figure 2.3-4 (Continued)

analysis. It is used to initialize the array calibration table if, for some reason, the BEAMFORMER CALIBRATION mode cannot be exercised. This mode exits to the Executive upon completion. In this mode, only one specific Cal table is forced to unity. The program determines which table by asking for the ARRAY TYPE and CAL TABLE No. SAMPLE RATE is also requested, so that all parameters for the stored table are properly stored. See Figure 2.3-5, for a typical input sequence.

2.3.4 Display Cal Table

(U) Choosing this selection will display the current values being stored in a particular table. Selecting this option will cause the questions ARRAY TYPE and CAL TABLE No. to be asked, followed by the selected table being printed on the list device. It should be appreciated that the stored calibration table is the reciprocal of the channel responses; consequently, the signs for the channel amplitudes and phases will be opposite from those printed out during the original calibration analysis. See Figures 2.3-6 and 2.3-7 for inputs and outputs.

2.4 BEAMFORMING

(U) The BEAMFORMING PROGRAM is called by entering B while in the Executive program. Prior to starting the first beamforming operation, the following steps must be taken:

1. All cabling and switch settings must be proper (see Section 2.1.3)

2. The array to be used must be calibrated using the BEAMFORMER CALIBRATION program.

3. The array shading table, array spacing plot format variables, sound velocity, date, and list device must be initialized using the EDITING program.

BUNKER RAMO

```
     ***** TAP-II CALIBRATION ANALYSIS *****
     5:42:19                    29 SEP 77

ENTER CAL TYPE:
                        1 = BEAMFORMER CALIBRATION
                        2 = NOISE ANALYSIS
                        3 = FORCE CAL TABLE TO UNITY
                        4 = DISPLAY CAL TABLE
(     Ø)
3
 ARRAY TYPE: (1=LF, 2=MF, 3=HF)
(     1)
 CAL TABLE NO: (1 - 2)
(     1)
 SAMPLE RATE (HZ): (2Ø.ØØ - 1ØØØ.ØØ)
(     53.ØØØ)
```

Figure 2.3-5

BUNKER RAMO

```
     ***** TAP-II CALIBRATION ANALYSIS *****
     2Ø:32:4Ø                     3 SEP 77

ENTER CAL TYPE:
                    1 = BEAMFORMER CALIBRATION
                    2 = NOISE ANALYSIS
                    3 = FORCE CAL TABLE TO UNITY
                    4 = DISPLAY CAL TABLE
(     Ø)
4
 ARRAY TYPE: (1=LF, 2=MF, 3=HF)
(     2)
 CAL TABLE NO: (1 - 2)
(     1)
```

Figure 2.3-6

BUNKER RAMO

STORED CALIBRATION TABLE 3 SEP 77 20:16:47 PAGE 1

ARRAY TYPE = 2		BLOCK SIZE =	32
		DELTA-F =	4.00
SAMPLE RATE = 128.00		CAL TABLE NO. =	1

		F = 12.0		F = 24.0		F = 36.0		F = 48.0	
CH	I*	AMPL.	ANGLE	AMPL.	ANGLE	AMPL.	ANGLE	AMPL.	ANGLE
1	R	.0	.2	.0	-.4	.1	-.8	.1	-1.9
2	R	-.0	-1.3	.1	-1.6	.1	-2.2	.3	-6.2
3	R	-1.2	-.4	-1.1	-.0	-1.0	1.2	-.0	.5
4	R	-.1	-1.5	-.2	-1.0	-.1	-1.3	.1	-6.7
5	R	.5	-4.3	.4	-2.3	.4	-1.8	.2	-2.3
6	R	-.4	-.8	-.3	.0	-.2	.4	.2	.3
7	R	.7	-1.8	.7	-1.2	.6	-1.0	.3	-1.0
8	R	.8	-.2	.8	-.7	.8	-1.6	.2	-3.7
9	R	-.8	-1.7	-.7	-.7	-.5	-.8	.0	-5.5
10	R	.2	-2.6	.1	-1.3	.2	-.8	.3	-4.5
11	R	.6	-1.7	.6	-1.4	.5	-1.3	.2	-2.8
12	R	.4	-2.9	.3	-1.5	.5	-2.0	.2	-8.5
13	R	-.2	-2.0	-.3	-1.6	-.1	-2.0	.1	-9.6
14	R	.1	-1.6	.0	-.9	.1	.0	.2	-1.2
15	R	.5	-.6	.4	-.1	.4	.2	.1	-.8
16	R	-.6	-1.4	-.6	-.5	-.3	-.6	.1	-5.9
17	R	.6	.4	.6	.4	.7	1.0	.3	-1.3
18	R	-.3	-.4	-.2	-.2	.0	-.7	.1	-5.7
19	R	.5	-2.2	.5	-.8	.7	-1.1	.2	-2.5
20	R	.1	.0	.1	-.5	.1	-1.0	.0	-1.6
21	R	-.1	-.6	-.1	-.6	-.1	-.7	.1	-4.1
22	R	-.2	-1.2	-.1	-.2	.1	-.2	.2	-3.9
23	R	.2	-1.3	.2	-.9	.2	-.7	.1	1.1
24	R	.0	-2.1	-.0	-.7	.1	.3	.2	-2.0
25	R	1.0	-3.0	1.0	-1.4	1.0	-1.5	.2	-1.0
26	R	-.3	-1.8	-.3	-.3	-.2	.9	.2	-.9
27	R	.7	-3.8	.6	-2.3	[illegible]	-2.4	.2	-7.1
28	R	.5	-1.0	.5	-.7	.6	-1.2	.3	-6.6
29	R	.1	1.0	.1	.6	.2	.3	.2	-3.0
30	R	.2	-2.4	.2	-1.7	.2	-2.0	-.1	-3.6
31	R	.8	-.5	.8	-.3	[illegible]	-.4	.2	-.7
32	R	-.0	.0	-.0	.0	-.0	.0	-.0	.0

Figure 2.3-7

BUNKER RAMO

STORED CALIBRATION TABLE 3 SEP 77 20116147 PAGE 2

BLOCK SIZE = 32

ARRAY TYPE = 2

DELTA-F = 4.00

SAMPLE RATE = 128.00

CAL TABLE NO. = 1

		F =	12.0	F =	24.0	F =	36.0	F =	48.0
CH	T*	AMPL.	ANGLE	AMPL.	ANGLE	AMPL.	ANGLE	AMPL.	ANGLE
33	R	-.7	-1.8	-.8	-1.1	-.8	-.2	-.2	-.3
34	R	.2	-2.0	.2	-1.1	.1	-.1	.1	.5
35	R	-.3	-2.0	-.4	-1.0	-.4	-.6	-.2	-.2
36	R	.2	.4	.2	.2	.3	-.1	.2	-2.2
37	R	-.3	-4.3	-.4	-2.1	-.3	-2.1	.0	-7.5
38	R	-.4	.3	-.4	-.0	-.3	-.2	-.0	-2.9
39	R	.6	.1	.5	-.4	.5	-.5	.1	-1.7
40	R	1.6	-4.8	1.3	-2.8	1.2	-3.3	.2	-5.3
41	R	-.9	-2.0	-.9	-1.4	-.8	-1.4	-.1	-6.6
42	R	-.1	-1.6	-.1	-.0	.1	.4	.2	-2.3
43	R	.4	-5.2	.2	-2.4	.2	-1.2	.1	-2.4
44	R	-.1	-1.1	-.2	-.5	-.2	.4	.1	.3
45	R	1.0	-1.7	[illegible]	-.6	.8	-.6	.1	-.7
46	R	[illegible]	-4.0	.5	-2.1	.4	-1.0	.1	.6
47	R	-.3	-1.0	-.3	-.2	-.1	.1	.2	-4.1
48	R	-.3	-1.2	-.4	-.1	-.3	1.0	-.0	.9
49	R	-.2	-2.2	-.3	-1.4	-.3	-1.2	.0	-8.3
50	R	.0	-2.1	-.0	-1.3	.0	-1.8	-.0	-3.8
51	R	-.2	.4	-.2	1.9	-.0	2.3	.1	-7.2
52	[illegible]	-.5	.1	-.5	.3	-.3	-.2	.1	-7.1
53	R	[illegible]	-3.3	.0	-1.7	.2	-1.8	.2	-8.7
54	R	.2	-1.2	2	-1.1	.2	-1.4	.1	-5.5
55	R	-.3	-2.7	-.3	-1.1	-.2	-1.2	-.0	-6.6
56	R	.6	-2.0	.6	-.6	.6	-2.5	.2	-6.3
57	R	.8	-1.0	.7	-.4	.7	-.4	.3	-1.2
58	R	.3	-.7	.3	-.5	.3	-.8	-.1	.8
59	R	.1	-4.5	-.1	-2.2	-.2	-1.1	-.0	-1.4
60	R	1	-1.2	.1	-.6	.2	-.8	.2	-4.0
61	R	-.0	-.4	-.0	.0	.1	.1	.1	-3.7
62	R	-.5	-1.9	-.6	-.7	-.6	.4	-.2	1.3
63	R	.5	-.3	.5	-.4	.6	-1.5	.3	-5.2
64	R	-3.2	7.6	1.7	4.7	-.5	17.2	-4.2	-8.0

Figure 2.3-7 (Continued)

4. The sample rate timing source must be set to the proper frequency.

5. The INPUT NEW PARAMETERS mode of the BEAMFORMING program must be entered to establish the operation to be performed.

(U) Subsequent beamforming operations may bypass the above steps if no change is desired.

(U) Upon entering the BEAMFORMING program, the operator has five entry options:

ENTER

1 TO INPUT NEW PARAMETERS
2 TO START IMMEDIATELY, USING PREVIOUS INPUTS
3 TO READ PARAMETERS FROM DISC FILE
4 TO DISPLAY EXISTING TABLE DATA

12345 TO RETURN TO EXEC

(U) See Figures 2.4-1 through 2.4-9 for typical prompt and operator response for Beamforming.

2.4.1 To Input New Parameters

(U) This mode is entered upon start up or when parameter changes are required. After the parameters have been updated, the program either writes these parameters on disc for future use or exits to the beamforming calculations. While in the INPUT NEW PARAMETERS mode, the operator may return to the Executive program without modifying any parameters by typing 12345. The parameters which may be changed are:

1. Analysis Parameters

ARRAY TYPE

TIME-FREQUENCY TRANSFORM LENGTH

BUNKER RAMO

```
***** TAP-II BEAMFORMING PROGRAM *****

5:26:38             7/29/77

ENTER                   1  TO INPUT NEW PARAMETERS

                        2  TO START IMMEDIATELY, USING PREVIOUS INPUTS

                        3  TO READ PARAMETERS FROM DISC FILE

                        4  TO DISPLAY EXISTING TABLE DATA

                    12345  TO RETURN TO EXEC

(     Ø)

1
```

Figure 2.4-1

BUNKER RAMO

```
ENTER ARRAY TYPE (1=LF, 2=MF, 3=HF)
(    1)
ENTER TIME-FREQUENCY TRANSFORM LENGTH:  1024, 2048, 4096)
(  4096)
ENTER SAMPLE RATE (HZ):  (20.  - 1000.)
(   53.000)
SET FREQ. SYNT. TO   90940.0 HZ.
ENTER SHADING TABLE NO.:  (1, 2, OR 3)
(    2)
ENTER TYPE OF TIME WEIGHTING WINDOW: (1=RECT, 2=HANNING, 3=RECT)
(    2)
ENTER TYPE OF AVERAGING:  (1=SIMPLE, 2=EXPONENTIAL)
(    1)
ENTER NUMBER OF AVERAGING INTERVALS:  (1 - 999)
(    5)
ENTER CAL TABLE NO:  (1 - 2)
(    1)
```

Figure 2.4-2

```
LINE GROUP FREQUENCY RANGES ARE:  (NO.   MIN.F   MAX.F)
    1      Ø      1.6    2   1.7     3.3    3    3.3     5.8    4    5.Ø    6.6
    5     6.6     8.3    6   8.3     9.9    7    9.9    11.6    8   11.6   13.2
    9    13.2    14.9   1Ø  14.9    16.5   11   16.6    18.2   12   18.2   19.9
   13    19.9    21.5   14  21.5    23.2   15   23.2    24.8   16   24.8   26.5

HOW MANY LINE GROUPS FOR ANALYSIS?  (1 - 8)
(    4)

THE CURRENT LINE GROUP NO (S) =  4  5  6  7
CHANGE DESIRED?  (1 = YES, Ø = NO)
(    Ø)
```

Figure 2.4-3

```
COMPLEX COEFF. OUTPUT:  ENTER Ø TO OUTPUT TO TAPE UNIT Ø
                              1 TO OUTPUT TO TAPE UNIT 1
                              2 TO INHIBIT OUTPUT
(    2)
ACCUM. TABLE OUTPUT:    ENTER Ø TO OUTPUT TO TAPE UNIT Ø
                              1 TO OUTPUT TO TAPE UNIT 1
                              2 TO INHIBIT OUTPUT
(    2)
```

Figure 2.4-4

BEAMFORMING PARAMETERS

ARRAY TYPE:	1
T-F XFORM LENGTH:	4Ø96
SHD TABLE NO:	2
TM WT WINDOW (1=R, 2=H):	2
AV TYPE (1=S, 2=E):	1
EXP AV TIME(SEC):	.Ø
NO AV INT:	5
SAMPLE RATE (HZ)	53.ØØØ
CAL TABLE NO:	1

TAPE UNITS (2 = NOT USED)

COMP. COEF:	2
ACCUM. TBL:	2

4 LINE GROUP (S) FOR ANALYSIS

GROUP NO.	MIN. F	MAX. F
4	4.97	6.61
5	6.62	8.27
6	8.28	9.92
7	9.94	11.58

ENTER START FLAG: (1 = START ANALYSIS, USING THESE PARAMETERS)
(2 = WRITE PARAMETERS TO DISC FILE)
(3 = RETURN TO START OF BEAMFORMING)
(12345 = RETURN TO EXEC)

(1)

2

ENTER FILE NO: (1 - 9)

(1)

9

Figure 2.4-5

BUNKER RAMO

```
FILE WRITEN



ENTER START FLAG:  (1 = START ANALYSIS, USING THESE PARAMETERS)

                   (2 = WRITE PARAMETERS TO DISC FILE)

                   (3 = RETURN TO START OF BEAMFORMING)

                   (12345 = RETURN TO EXEC)

(     1)

1
```

Figure 2.4-6

```
*****TAP-II BEAMFORMING PROGRAM*****
5:37:37                    7/29/77
ENTER               1 TO INPUT NEW PARAMETERS
                    2 TO START IMMEDIATELY, USING PREVIOUS INPUTS
                    3 TO READ PARAMETERS FROM DISC FILE
                    4 TO DISPLAY EXISTING TABLE DATA
                12345 TO RETURN TO EXEC
(     Ø)
3
ENTER DISC FILE NO:  (1 - 9)
(     Ø)
9
```

Figure 2.4-7

BEAMFORMING PARAMETERS

ARRAY TYPE	1
T-F FORM LENGTH	4Ø96
SHD TABLE NO.	2
TM WT. WINDOW(1=R,2=H)	2
AV TYPE (1=S,2=E)	1
EXP AV TIMEX (SEC.)	Ø
NO. AV. INT.	5
SAMPLE RATE (HZ)	53.ØØØ
CAL TABLE NO:	1

TAPE UNITS (2 = NOT USED)

COMP. COEF	2
ACCUM. TBL	2

4 LINE GROUP (S) FOR ANALYSIS

GROUP NO.	MIN. F	MAX. F
4	4.97	6.61
5	6.62	8.27
6	8.28	9.92
7	9.94	11.58

ENTER START FLAG: (1 = START ANALYSIS, USING THESE PARAMETERS)
(2 = WRITE PARAMETERS TO DISC FILE)
(3 = RETURN TO START OF BEAMFORMING)
(12345 = RETURN TO EXEC)

(1)

1

Figure 2.4-8

```
SET THE FOLLOWING SENSE SWITCHES:

         SS  Ø TO OUTPUT LINE GROUP NO. 4

         SS  1 TO OUTPUT LINE GROUP NO. 5

         SS  2 TO OUTPUT LINE GROUP NO. 6

         SS  3 TO OUTPUT LINE GROUP NO. 7


CLEAR SWITCH 8 TO PLOT LINE GROUP DATA, SET TO LIST

CLEAR SWITCH 9 FOR FULL LISTING, SET FOR PARTIAL

CLEAR SWITCH 1Ø FOR NORMAL END, SET TO LOOP AROUND


CURRENT SAMPLE RATE =  53.Ø HZ

SET FREQ. SYNT. TO     9Ø948. HZ AND HIT RETURN


INTERVAL NO. 1 OF 5 SAMPLE INTERVAL (S)

INTERVAL NO. 2 OF 5 SAMPLE INTERVAL (S)
```

Figure 2.4-9

SAMPLE RATE

SHADING TABLE No. (normal shading table is Hanning)

TIME WEIGHTING WINDOW (normal weighting window is Hanning)

TYPE OF AVERAGING (normal averaging is simple)

NUMBER OF AVERAGING INTERVALS (normal entry is 5)

CAL TABLE No.

2. Output Parameters

HOW MANY LINE GROUPS FOR ANALYSIS

ENTER THE LINE GROUP NUMBERS

COM COEF

ACC TBL

(U) Each of these parameter entries is discussed below.

2.4.1.1 Array Type. (C) Enter 1 for LF, 2 for MF, or 3 for the HF array.

2.4.1.2 Time-Frequency Transform Length. (U) This parameter (which can be 1024, 2048, or 4096), together with the following SAMPLE RATE parameter, determines the analysis bandwidth. The formula used is

$$\text{Bandwidth} = \frac{\text{Sample Rate}}{\text{T-F xform length}}$$

(U) T-F Transform Length, Sample Rate, Array Type, and the setting of the Lambda Filter Switch are all inter-related. Recommend combinations of these parameters are given in Figure 2.4-10, together with the resulting analysis bandwidth, maximum recommended analysis frequency, and frequency synthesizer setting. Throughput is maximized when a 4096 point transform length is selected.

2.4.1.3 Sample Rate (U) The sample rate primarily depends upon the filter set selected (see Figure 2.4-10). When a sample rate is selected, the computer prints out the correct frequency synthesizer setting (which is 1716 x Sample Rate).

ARRAY TYPE	FILTER SET	T-F XFORM LENGTH	SAMPLE RATE (HZ)	FREQ. SYNT. SETTING (HZ)	ANALYSIS BANDWIDTH (HZ)	MAX. USABLE FREQ. (HZ)
LF	LF	1024	64	109,824.0	1/16	20.0
LF	LF	2048	64	109,824.0	1/32	20.0
LF	LF	4096	64	109,824.0	1/64	20.0
LF	MF	1024	128	219,648.0	1/8	53.0
LF	MF	2048	128	219,648.0	1/16	53.0
LF	MF	4096	128	219,648.0	1/32	53.0
MF	MF	1024	128	219,648.0	1/8	53.0
MF	MF	2048	128	219,648.0	1/16	53.0
MF	MF	4096	128	219,648.0	1/32	53.0
MF	HF	1024	512	878,592.0	1/2	160.0
MF	HF	2048	512	878,592.0	1/4	160.0
MF	HF	4096	512	878,592.0	1/8	160.0
HF	HF	1024	819.2	1,405,747.2	0.8	320.0
HF	HF	2048	819.2	1,405,747.2	0.4	320.0
HF	HF	4096	819.2	1,405,747.2	0.2	320.0

Figure 2.4-10. Recommended TAP II Parameter Combinations

(U) It is necessary to set the sample rate to the same value it was set at when the selected calibration table was made. The computer checks for this during execution, and halts with an error message if incorrect.

2.4.1.4 Shading Table. (U) One of three shading tables for each array can be selected. The table selected must have been previously initialized during EDITING, or improper answers will result.

(U) The Lambda convention is to set Table No. 1 to unity, and Tables 2 and 3 to Hanning. A Hanning Table is usually selected.

2.4.1.5 Type of Averaging. (U) TAP-II can use simple (linear), or exponential averaging, whichever the operator desires. Simple is usually chosen. If exponential is chosen, the computer will ask for the averaging time in seconds.

2.4.1.6 No. of Averaging Intervals. (U) TAP-II analyzes over a preset number of averaging cycles, the number of cycles is entered here. Five is the number usually chosen.

(U) To let the operator know which loop the computer is in, each averaging interval number is printed out during execution (see Figure 2.4-9).

2.4.1.7 Calibration Table No. (U) Two calibration tables can be stored by TAP-II for each array. Either one can be used, but the operator must be sure that the one selected was properly set up during a preceding CALIBRATION analysis.

2.4.1.8 Line Group Selection. (C) TAP-II does all analysis in groups of 128 frequency lines. A single group of 128 lines is called a line group. For a 1024 point T-F transform, the operator can select up to four line groups for analysis. For either 2048 or 4096 T-F transfrom lengths, the operator can select up to eight line groups.

(U) The line groups selected depend only upon the frequency ranges of interest. To aid the operator select these groups, TAP-II first prints out all the line groups available, together with the minimum and maximum frequency contained in each group (see Figure 2.4-3). The line groups currently selected are then listed and the operator asked if a change is desired by the question:

CHANGE DESIRED (1 = YES, 0 = NO)

(U) If a change is desired (1 entered), the operator is instructed to enter the list of groups desired. The group numbers are entered on one line, in ascending order, separated by spaces.

(U) It is mathematically possible for TAP-II to analyze frequencies up to one-half the sample rate. However, because of filter limitations, frequencies above those recommended in Figure 2.4-10 should not be used.

2.4.1.10 Complex Coefficient Output. (U) The complex beamforming coefficients output by TAP-II can be written to magnetic tape. In answer to the Complex Coefficient question, the operator can answer:

0 to output to tape unit 0
1 to output to tape unit 1
2 to inhibit output

(U) Whenever output is written, the operator must enable the tape unit with the proper unit number selected, and mount a tape with a write ring. TAP-II checks for proper tape unit status before writing, and audibly informs the operator if the tape unit is not ready.

(U) After each tape record, TAP-II writes a single end-of-file, then backspaces. Consequently, an end-of-file is at the end of tape whenever it is dismounted. If the physical END OF TAPE is encountered during execution, TAP-II will write an end-of-file, then rewind the

tape, and also ring the bell on the CRT to inform the operator. The operator can then mount another tape.

2.4.1.11 Accumulator Table. (U) The beamformer output indexed to frequency and steer angle can also be written on magnetic tape. The questions and procedures for this option are identical to the Complex Coefficient Output, described above.

(U) The tape unit number selected can be the same as, or differ from, the unit selected for Complex Coefficients. If different, two tape decks must be daisy-chained together.

2.4.2 Disc Storage and Retrieval of Parameters

(U) At end of an Input New Parameters sequence, a summary of all parameters entered is written by the computer on the CRT screen (see Figure 2.4-5). This summary is followed by the message:

```
ENTER START FLAG:  (1 = START ANALYSIS, USING THESE
                        PARAMETERS)
                   (2 = WRITE PARAMETERS TO DISC FILE)
                   (3 = RETURN TO START OF BEAMFORMING):
                   (12345 = RETURN TO EXEC)
```

(U) The user can start beamforming by entering 1. However, the parameters can be permanently stored on disc by entering 2. The computer will then ask:

```
ENTER FILE NO:  (1-9)
```

(U) When the user answers, the parameters are written to the selected file. In this manner, up to 9 different parameter sets can be written on disc.

(U) To retrieve a parameter set from disc and use it for beamforming, the procedure shown in Figures 2.4-7 and 2.4-8 is used when the beamforming analysis is started.

2.4.3 Sense Switch Selection and Beamforming Execution

(U) Beamforming can be started three ways: (1) by inputting new parameters, (2) by retrieving parameters from disc file, or (3) by starting immediately, using the parameters from the most recent analysis (see Figures 2.4-1). With any of these methods, the message shown in Figure 2.4-9 is the final message written on the CRT by TAP-II. This message gives the instructions for setting the sense switches and the frequency synthesizer. The operator then sets the switches as desired and enters RETURN on the keyboard to start analysis. The sense switch options are given in Figure 2.4-11.

(U) During execution, the current sample interval is always printed on the CRT screen.

2.4.4 Start Immediately

(U) This option is chosen by entering 2 to the question shown on Figure 2.4-1. It causes TAP-II to use the parameters for the most recent analysis over again.

2.4.5 To Display Existing Table Data

(U) This option allows previously analyzed data to be printed and/or plotted with the same or new plot variables. For example, it may be desirable to change the scale, range, plot angle, etc., to emphasize features of interest. At the completion of the BEAMFORMING analysis, control is returned to the Executive program. If plot changes are desired, the operator should enter the Edit routine, call Plot Format Variables, and make the changes desired. Upon re-entering the BEAMFORMING Program, via the Executive Program, the operator enters 4 and

SS No.	Option
0	The first eight switches determine which line groups are plotted or listed if a complete listing is selected (see switch 9). The computer prints out a message informing the operator which line group each of these switches controls.
1	
2	
3	
4	
5	
6	
7	
8	If switch 8 is cleared, the line groups selected by switches 0-7 are plotted on the CRT. If set, the data is printed on the line printer.
9	If listing is selected by switch 8, switch 9 determines the type of listing. If switch 9 is clear, the line groups selected by switches 0-7 are listed in their entirely (128 frequency lines, 64 steer angles for each line). If switch 9 is set, the operator is requested to enter the frequency of interest via the CRT, and 44 lines around this frequency are listed on the line printer (64 steer angles for each line).
10	If switch 10 is clear, the beamforming program returns to the Executive after the analysis. If set, a loop is set up where beamforming is automatically restarted after each completion, using the originally input parameters. Output to the line printer and CRT are inhibited, but the IBM tapes are written.

Figure 2.4-11. Sense Switch Options

RETURN to output the previously analyzed data. Sense switches should be set to the configuration for the output desired prior to depressing RETURN.

2.4.6 12345 to Return to EXEC

(U) While in the BEAMFORMING program initializing phase, the operator may return to the Executive program by typing 12345 in response to any prompt message. This action terminates the new parameter input and uses old parameters in subsequent analysis.

2.4.7 TAP-II Outputs

(U) TAP-II has several forms of outputs. Magnetic tape outputs for both beamformer complex coefficients and for accumulation tables are available, and these formats are described in Appendix B.

(C) Graphical outputs are displayed on the CRT screen, and an example is shown in Figure 2.4-12. Two line groups per page are plotted, in a pseudo-isometric format. All critical TAP-II analysis parameters are also shown on the same page. Frequency is the plot ordinate, with one line group comprising the left half of the plot and the second group, the right. The ordinate is power in dBv. The depth dimension is the TAP-II beam number from 1 to 64, with 1 being the most forward and 64 the most rearward steer angle. The correspondence between beam number and steer angle is shown in Figure 2.4.13, for unaliased beams. For unaliased beams, this correspondence between beam number and steer angle is constant, since TAP II automatically makes this correction. For aliased beams (above 20 Hz for the LF, 60 Hz for the MF, and 337 Hz for the HF), the beams are not interpolated, and any correction must be done by the operator. This is also true for the listed outputs.

(C) Two types of listings are available, as selected by the sense switches. A full listing lists powers in dBv for all 64 steer angles

BUNKER RAMO

TAP II ANALYSIS	3 SEP 77 20:42:37
SHD TBL NO. = 3	NO. AVG. INT = 4
T-F XFORM. = 1024	F. RANGE, GRP. 2 = 16.0 TO 31.9
2 PLOT FMT	F. RANGE, GRP. 3 = 32.0 TO 47.9
ARRAY TYPE = 2	
SAMP. RATE = 128	
ANAL. B. W. = 13	
TIM-WT WNDO = 2	

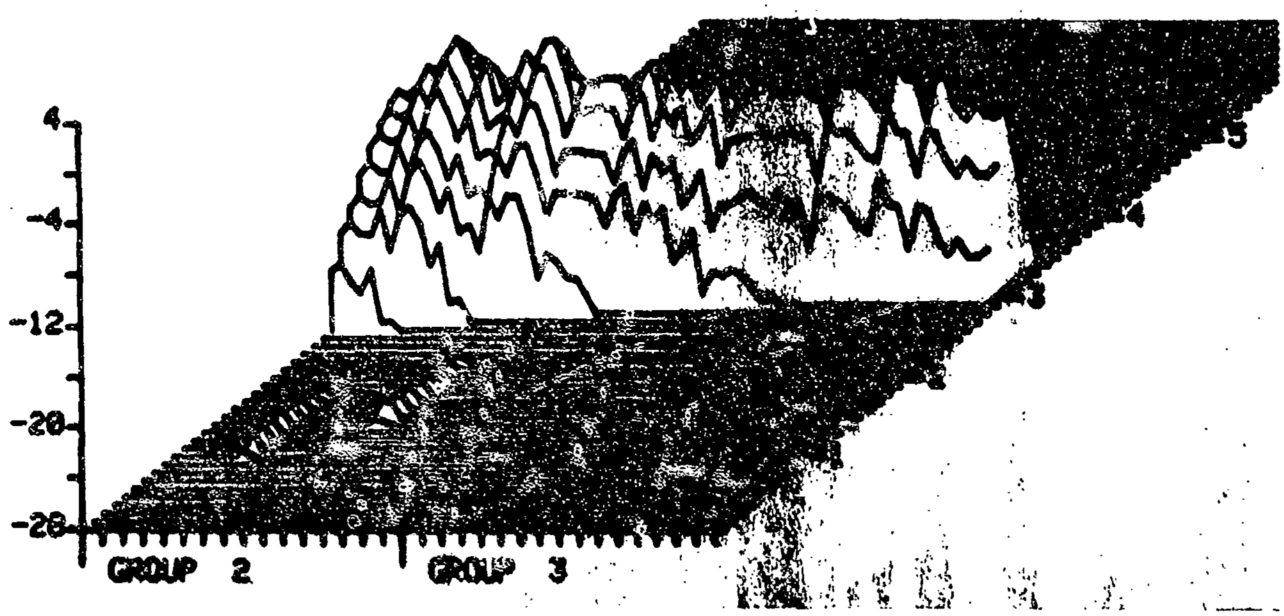

Figure 2.4-12

TAP II STORED DATA
DATE 16 APR 1977 TIME 5:46:17

ARRAY NO	SAMPLE RATE (HZ)	SPACING (METERS)	ARRAY ALIASING FREQ. (HZ)
1	53.ØØ	37.5ØØ	2Ø.ØØ
2	135.68	12.5ØØ	6Ø.ØØ
3	848.ØØ	2.344	319.97

SOUND VELOCITY = 15ØØ.Ø

TAP II STANDARD STEER ANGLES (DEGREES)

1: -75.47	2: -69.55	3: -64.96	4: -61.Ø4
5: -57.46	6: -54.29	7: -51.35	8: -48.59
9: -45.89	1Ø: -43.39	11: -41.ØØ	12: -38.68
13: -36.37	14: -34.19	15: -32.Ø7	16: -3Ø.ØØ
17: -27.9Ø	18: -25.91	19: -23.95	2Ø: -22.Ø2
21: -2Ø.Ø6	22: -18.18	23: -16.32	24: -14.48
25: -12.59	26: -1Ø.78	27: -8.97	28: -7.18
29: -5.34	3Ø: -3.55	31: -1.78	32: .ØØ
33: 1.78	34: 3.55	35: 5.34	36: 7.18
37: 8.97	38: 1Ø.78	39: 12.59	4Ø: 14.48
41: 16.32	42: 18.18	43: 2Ø.Ø6	44: 22.Ø2
45: 23.95	46: 25.91	47: 27.9Ø	48: 3Ø.ØØ
49: 32.Ø7	5Ø: 34.19	51: 36.37	52: 38.68
53: 41.ØØ	54: 43.39	55: 45.89	56: 48.59
57: 51.35	58: 54.29	59: 57.46	6Ø: 61.Ø4
61: 64.96	62: 69.55	63: 75.47	64: 9Ø.ØØ

PRESS RETURN TO CONTINUE

Figure 2.4-13. Sample Display Stored Data Printout

and all 128 lines in the selected line groups, for a total of 8192 numbers per group. This takes 12 line-printer pages for each line group listed.

(C) If a partial listing is selected, the operator is asked, via the CRT, for the desired frequency. A listing of 1/3 of a line group then results, powers in dBv for all 64 angles for the third of the line group which contains the desired frequency. This takes four line-printer pages. A single page of listing is shown in Figure 2.4-14. The operator should realize that as in the graphical outputs, the listed steer angles are valid only below the array aliasing frequency.

2.5 EDITING

(U) Editing allows the modification of certain infrequently changed parameters. This function is selected by entering an E when in the Executive.

(U) The Editing program will display the following on the CRT:

PARAMETER EDITING PHASE

ENTER DATA SET TO BE MODIFIED:

1 = ARRAY SHADING TABLES
2 = ARRAY SPACING
3 = ARRAY SAMPLING RATES
4 = PLOT FORMAT VARIABLES
5 = SOUND VELOCITY
6 = DATE
7 = LIST DEVICE
8 = RETURN TO EXECUTIVE

(U) The operator may select any of these functions in any order. The only requirement is that after he is through, he must select function 8 (Return to Executive) so that the modified data will be stored on disc.

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T A P   I I   B E A M F O R M I N G   A N A L Y S I S

3 SEP 77   20:42:37   PAGE 1

LINE GROUP NO = 2
TIME-FREQUENCY
TRANSFORM LENGTH = 1024
SHADING TABLE NO = 2
TYPE OF AVERAGING = 1 (1=SIMPLE)

ARRAY TYPE = 2
TIME WEIGHTING
WINDOW TYPE = 2
AVERAGING INTERVALS = 4

LINE NO	FREQ (HZ)	STEER ANGLE (DEGREES) 75.5	69.6	65.0	61.0	57.5	54.3	51.3	48.6	45.9	43.4	41.0	38.7	36.4	34.2	32.1	30.0
44	21.50	-35.7	-36.3	-37.2	-38.2	-38.6	-38.9	-38.9	-37.0	-35.6	-34.6	-34.1	-33.5	-33.2	-32.9	-32.7	-32.9
45	21.62	-36.6	-36.9	-37.4	-38.0	-38.2	-38.2	-38.2	-37.4	-36.4	-35.6	-34.4	-33.5	-33.0	-33.2	-33.5	-33.5
46	21.75	-35.6	-35.7	-36.6	-37.4	-38.0	-38.0	-38.0	-37.0	-35.9	-35.0	-34.0	-33.2	-32.5	-32.5	-32.4	-32.5
47	21.87	-35.4	-35.4	-35.6	-35.9	-36.1	-36.1	-36.3	-36.1	-35.6	-35.3	-33.3	-31.9	-30.9	-31.4	-32.0	-32.7
48	22.00	-34.9	-34.9	-35.2	-35.4	-35.6	-36.0	-36.6	-36.3	-35.0	-34.2	-32.9	-31.7	-30.8	-30.9	-31.1	-31.3
49	22.12	-37.8	-37.8	-38.4	-39.1	-39.7	-39.7	-39.7	-39.4	-37.8	-36.7	-35.9	-35.0	-34.5	-34.4	-34.4	-34.5
50	22.25	-36.9	-36.9	-36.9	-36.9	-36.9	-37.0	-37.6	-37.8	-36.7	-36.0	-34.6	-33.2	-32.0	-32.1	-32.4	-32.9
51	22.37	-36.6	-36.1	-35.9	-36.4	-36.7	-36.9	-36.9	-36.9	-36.1	-35.4	-34.5	-32.9	-31.8	-31.8	-32.3	-32.9
52	22.50	-38.2	-37.4	-37.0	-37.0	-38.6	-38.9	-38.6	-38.4	-37.4	-36.4	-35.5	-34.3	-33.3	-33.0	-33.3	-33.5
53	22.62	-42.1	-40.8	-40.4	-40.8	-41.2	-41.6	-41.6	-41.6	-40.8	-39.7	-38.6	-37.4	-36.6	-36.1	-36.4	-36.7
54	22.75	-38.4	-37.6	-37.2	-37.4	-37.6	-38.0	-38.4	-39.1	-38.2	-37.0	-36.0	-34.7	-33.8	-33.3	-33.4	-33.4
55	22.87	-38.4	-36.6	-35.6	-35.9	-36.9	-38.2	-38.2	-38.2	-37.2	-35.5	-34.3	-33.6	-33.0	-32.5	-32.2	-32.0
56	23.00	-41.2	-38.2	-36.7	-36.9	-38.6	-40.4	-40.0	-39.7	-38.6	-37.0	-36.0	-35.3	-34.8	-34.5	-34.0	-33.6
57	23.12	-39.4	-38.2	-37.2	-37.0	-38.0	-38.9	-38.9	-38.6	-38.2	-37.0	-36.3	-35.3	-34.3	-33.5	-33.5	-33.5
58	23.25	-38.9	-38.2	-37.4	-36.9	-37.4	-38.0	-38.4	-38.4	-38.4	-37.4	-36.4	-35.2	-33.8	-32.7	-33.0	-33.5
59	23.37	-34.0	-33.3	-32.4	-31.7	-32.2	-32.7	-33.0	-33.2	-33.4	-32.1	-31.1	-30.0	-28.7	-27.7	-27.7	-27.9
60	23.50	-35.6	-35.0	-33.9	-33.2	-33.6	-34.4	-34.8	-35.0	-35.2	-33.8	-32.5	-31.5	-30.4	-29.6	-29.4	-29.3
61	23.62	-41.2	-40.8	-39.4	-38.4	-38.6	-39.7	-40.4	-40.4	-40.4	-39.1	-37.8	-36.7	-35.9	-35.2	-34.8	-34.7
62	23.75	-36.1	-36.1	-35.2	-34.5	-34.5	-34.9	-35.5	-35.9	-36.1	-35.2	-33.7	-32.6	-31.6	-30.8	-30.5	-30.5
63	23.87	-35.0	-35.0	-34.4	-33.8	-33.6	-33.9	-34.1	-34.5	-35.0	-34.5	-33.2	-32.2	-30.8	-29.7	-29.4	-29.6
64	24.00	-37.3	-37.3	-37.2	-37.0	-36.9	-36.8	-36.7	-37.3	-38.1	-38.0	-36.3	-35.2	-33.7	-32.7	-32.1	-32.4
65	24.12	-36.1	-36.4	-35.9	-35.2	-34.7	-35.1	-35.4	-35.9	-36.5	-36.4	-34.6	-33.4	-32.2	-31.2	-30.7	-30.7
66	24.25	-35.1	-35.1	-34.2	-32.8	-31.9	-32.7	-33.5	-34.0	-34.1	-34.0	-32.4	-31.2	-30.2	-29.3	-28.8	-28.7
67	24.37	-33.5	-33.1	-32.4	-31.3	-30.5	-31.0	-31.7	-32.1	-32.1	-32.1	-30.9	-30.1	-28.9	-27.6	-26.7	-26.9
68	24.50	-34.7	-34.1	-33.5	-32.5	-31.7	-31.9	-32.5	-32.9	-32.6	-32.3	-31.8	-31.4	-30.2	-28.6	-27.4	-27.4
69	24.62	-33.5	-33.2	-32.9	-31.5	-30.5	-30.6	-31.4	-32.0	-32.1	-32.2	-31.1	-30.0	-28.9	-27.7	-26.8	-26.8
70	24.75	-37.1	-37.0	-36.9	-35.6	-34.4	-34.3	-35.1	-35.9	-35.9	-35.9	-34.9	-33.9	-32.8	-31.6	-30.7	-30.7
71	24.87	-41.4	-41.6	-41.6	-40.4	-39.3	-39.0	-39.9	-40.8	-40.4	-40.0	-39.3	-38.4	-37.6	-36.3	-35.3	-35.3
72	25.00	-39.9	-39.6	-39.1	-38.2	-37.1	-36.6	-37.5	-38.5	-38.6	-38.6	-37.8	-36.4	-35.4	-34.1	-33.2	-33.0
73	25.12	-37.4	-37.2	-37.0	-36.3	-35.3	-34.6	-35.2	-35.7	-36.1	-36.3	-35.9	-34.4	-33.3	-32.0	-31.1	-30.8
74	25.25	-35.3	-35.4	-35.4	-34.0	-33.2	-32.4	-33.0	-34.1	-34.4	-34.1	-33.5	-32.2	-31.2	-30.2	-29.3	-28.9
75	25.37	-35.2	-35.4	-35.6	-35.2	-33.3	-32.1	-32.8	-34.1	-34.7	-34.3	-33.8	-32.6	-31.7	-30.5	-29.4	-29.0
76	25.50	-39.9	-39.9	-39.9	-39.7	-37.9	-36.6	-36.8	-37.6	-38.2	-38.2	-38.1	-37.1	-36.3	-34.9	-33.6	-33.0
77	25.62	-41.2	-41.4	-41.6	-41.9	-39.7	-38.3	-38.5	-39.9	-41.0	-40.4	-39.7	-38.9	-38.1	-36.9	-35.7	-35.1
78	25.75	-42.4	-42.7	-43.4	-43.0	-42.4	-41.0	-40.8	-41.6	-43.0	-43.4	-44.2	-41.6	-39.6	-38.7	-38.5	-38.1
79	25.87	-38.5	-38.3	-38.5	-38.5	-37.1	-35.7	-35.3	-36.4	-37.9	-37.3	-36.8	-35.7	-34.7	-33.7	-32.7	-31.9
80	26.00	-36.4	-36.4	-36.6	-36.8	-35.7	-34.8	-33.3	-34.4	-35.9	-35.7	-35.2	-34.2	-33.0	-32.0	-31.0	-30.2
81	26.12	-36.4	-36.7	-36.9	-36.9	-36.2	-34.5	-33.6	-34.6	-35.9	-36.0	-35.7	-34.7	-33.4	-32.3	-31.2	-30.4
82	26.25	-37.2	-37.7	-37.8	-37.8	-37.3	-35.7	-34.6	-35.4	-36.3	-36.6	-36.4	-35.7	-34.5	-33.5	-32.1	-31.0
83	26.37	-36.6	-38.0	-38.1	-36.5	-35.5	-35.4	-35.4	-35.1	-34.8	-35.1	-35.7	-35.7	-34.5	-33.5	-31.5	-30.1
84	26.50	-35.7	-36.6	-37.1	-36.5	-36.0	-34.8	-33.9	-34.1	-34.7	-35.0	-35.0	-34.7	-33.6	-32.8	-31.2	-30.9
85	26.62	-40.0	-40.2	-40.4	-40.6	-40.6	-39.0	-37.8	-38.0	-39.1	-39.7	-39.4	-38.9	-37.8	-36.9	-35.4	-34.3
86	26.75	-41.0	-41.4	-42.4	-42.7	-42.7	-41.0	-39.1	-39.1	-40.8	-41.9	-41.0	-40.2	-39.3	-38.6	-37.2	-36.0
87	26.87	-37.9	-38.2	-38.4	-38.4	-38.6	-37.4	-36.1	-35.7	-36.6	-37.5	-37.6	-37.6	-36.0	-34.8	-33.5	-32.4

Figure 2.-4-14

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(U) The operator entries for each option are fairly self-explanatory. The following discussion refers to illustrations of typical displays for the particular option being described.

2.5.1 Array Shading Tables (See Figure 2.5-1)

(U) For each of the three arrays, there are three shading tables. The first two entries specify which of the nine tables is to be modified. It should be noted that there is no entry for the second request. This indicates that the operator selected the number in parentheses (1). The program then displays the current content of the table, and asks how the table is to be modified. If the option for individual changes is requested, as is shown, the program will request location and new value until 65 is entered for location. If the option for setting the entire table to one value is selected, the program will request that value and store it throughout the table. If the option for Hanning weightings is chosen, the Hanning weighting curve will be stored.

2.5.2 Array Spacing (See Figure 2.5-2)

(U) For each of the three arrays, there is a storage location for the element spacing. The two requests are for array number and element spacing in meters.

2.5.3 Array Sampling Rates (See Figures 2.5-3 and 2.5-4)

(U) For each of the three arrays, there is a storage location for the sampling rate. The first request is for array number. The second request (RECORDER USED FOR INPUT?) is significant because only certain predetermined sampling rates are allowed if the recorder is used. In this case, a list of rates is displayed and the operator must enter the number of the desired rate. When the recorder is not used, the actual sampling rate is entered. In either case, the required frequency synthesizer setting for the specified sampling rate is computed and displayed. The operator must adjust the sample rate source as requested.

```
ENTER ARRAY NUMBER:  (1-LF, 2=MF, 3=HF)
(    1)

ENTER TABLE TO BE MODIFIED (1-3)
(    1)

 1:   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000
 9:   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000
17:   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000
25:   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000
33:   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000
41:   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000
49:   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000
57:   1.000   1.000   1.000   1.000   1.000   1.000   1.000   1.000

ENTER CHANGE MODE (1-4)
1=SET ENTIRE TABLE TO SAME VALUE
2=SET TABLE TO HANNING WEIGHTINGS
3=MODIFY INDIVIDUAL VALUES
4=NO CHANGE
(    4)
3
ENTER TABLE LOCATION TO BE CHANGED (65=EXIT)
(    1)

ENTER NEW VALUE (0.0-100.0)
(     1.000)
0
ENTER TABLE LOCATION TO BE CHANGED (65=EXIT)
(    1)
65
```

Figure 2.5-1. Sample Array Shading Table Dialog

```
ENTER DATA SET TO BE MODIFIED:
 1=ARRAY SHADING TABLES
 2=ARRAY SPACING
 3=ARRAY SAMPLING RATES
 4=PLOT FORMAT VARIABLES
 5=SOUND VELOCITY
 6=DATE
 7=LIST DEVICE
 8=RETURN TO EXECUTIVE
2
ENTER ARRAY NUMBER   (1=LF, 2=MF, 3=HF)
(     1)

ENTER NEW SPACING IN METERS (0.0-150.0)
(     37.500)
```

Figure 2.5-2. Sample Array Spacing Dialog

```
ENTER ARRAY NUMBER:  (1=LF, 2=MF, 3=HF)
(    1)

RECORDER USED FOR INPUT? (Y OR N)
N
ENTER NEW SAMPLING RATE IN HERTZ (10.0-1000.0)
     53.000)

NEW FREQ. SYNTHESIZER SETTING IS   90.948 KHZ
```

Figure 2.5-3. Sample Array Sampling Rates Dialog (No Recorder)

```
ENTER ARRAY NUMBER:  (1=LF, 2=MF, 3=HF)
(    1)

RECORDER USED FOR INPUT?(Y OR N)
Y
ENTER SAMPLING RATE NUMBER (0-15):
    0=848.0    4=169.6    8= 94.2   12= 65.2
    1=424.0    5=141.3    9= 84.8   13= 60.6
    2=282.7    6=121.1   10= 77.1   14= 56.5
    3=212.0    7=106.0   11= 70.7   15= 53.0
(   15)

NEW FREQ. SYNTHESIZER SETTING IS    1.305 KHZ
```

Figure 2.5-4. Sample Array Sampling Rates Dialog (with Recorder)

2.5.4 Plot Format Variables (See Figure 2.5-5)

(U) The Plot Format Variables editing section allows modification of a series of numbers which specify the dimensions of the plot made by the BEAMFORMING program and what the plot represents. Most of the specifications are dimensioned in plot points. The CRT screen is 1000 plot points wide and 800 plot points high; 100 plot points are therefore one tenth of the screen width. Taking the plot format requests in order, the X and Y offsets of axis origin are the distance of the lower left hand corner of the plot from the left side and bottom of the CRT, respectively. X increment is the horizontal spacing of each of the 128 frequency bins which make up the horizontal axis. The width of the plot, therefore, is this number times 128. Plot height is the size of the Y axis. Delta X and delta Y plot-to-plot are the offset from one beam to the next. Varying them will change the apparent angle the Z axis makes with the X and Y axes. (The Z axis is the diagonal line at the right of the plot which is actually perpendicular to the XY plane). Lowest plot value is the lowest value on the Y axis, in decibels. Range plotted is the range of signals represented by the distance specified by the plot height Therefore, if the plot height is 304, the lowest plot value is -35 and the range plotted is 40, a level of 5 db, which is 40 above -35 db, will be 304 plot points higher than the -35 db level, or the bottom of the plot. The number of frequency lines to "OR" may be a 1 or 4. If 1 is selected, a normal plot results. If 4 is selected, only the highest within each group of four points is plotted, resulting in a much faster plot. The number of beams to skip at the beginning and end of plot, if other than 0, cuts off sections at the front or rear, respectively, of the plot. This prevents "mountains" at the front of the plot from hiding an important feature, or noise at the rear of the plot from obscuring one. An entry of zero provides a full plot.

```
PLOT FORMAT VARIABLES
X OFFSET OF AXIS ORIGIN (IN PLOT POINTS, 0-1000)
(   50)

Y OFFSET OF AXIS ORIGIN (IN PLOT POINTS, 0-1000)
(   60)

X INCREMENT (IN PLOT POINTS, 0-1000)
(    3)

PLOT HEIGHT (IN PLOT POINTS, MUST BE A MULTIPLE OF 8, 0-1000)
(  304)

DELTA X PLOT-TO-PLOT (IN MULTIPLES OF INCRX, 0-1000)
(    1)

DELTA Y PLOT-TO-PLOT (IN PLOT POINTS, 0-1000)
(    6)

LOWEST PLOT VALUE IN DB (-100.0 - +100.0)
(   -35.000)

RANGE PLOTTED IN DB (MUST BE A MULTIPLE OF 4, 0.0-200.0)
(    40.000)

NUMBER OF FREQUENCY LINES TO 'OR' FOR PLOT (1 OR 4)
(    4)

NUMBER OF BEAMS TO SKIP AT BEGINNING OF PLOT (0-65)
(   15)
0
NUMBER OF BEAMS TO SKIP AT END OF PLOT (0-65)
(   25)
0
```

Figure 2.5-5. Sample Plot Format Variables Dialog

2.2.5 Sound Velocity (See Figure 2.5-6)

(U) Sound velocity is entered in meters per second.

2.5.6 Date (See Figure 2.5-7)

Any 12 characters representing date may be entered. If the CHANGE DATE? question is answered with N (no), the current date is not modified.

2.5.7 List Device (See Figure 2.5-8)

(U) Either the CRT or the Teletype may be used as an alternate output device for messages which usually go to the line printer. This is generally only used as a backup in the event of a line printer failure. When the CRT is used, the computer must be halted at the bottom of each page and PAGE pressed if overwriting of the CRT screen is not desired. In the message, LP indicates line printer and TTY indicates Teletype.

2.5.8 Return to Executive

(U) After modifying any data, it is required that option 8 be selected to return control to the Executive, so that the new data will be written on the disc. Any other path back to the Executive will not save the new data.

2.6 DISPLAY STORED DATA

(U) The display stored data option allows listing of certain variables stored on the disc. In addition, the aliasing frequency for each of three array spacings at the current sound velocity is computed and printed. The standard steer angles for the interpolated beams are also listed. A choice of listing device is offered to the operator. An example of the printout is shown in Figure 2.4-13.

```
ENTER DATA SET TO BE MODIFIED:
 1=ARRAY SHADING TABLES
 2=ARRAY SPACING
 3=ARRAY SAMPLING RATES
 4=PLOT FORMAT VARIABLES
 5=SOUND VELOCITY
 6=DATE
 7=LIST DEVICE
 8=RETURN TO EXECUTIVE
5
ENTER SOUND VELOCITY IN METERS/SEC (0.0-3000.0)
(  1500.000)
```

Figure 2.5-6. Sample Sound Velocity Dialog

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```
ENTER DATA SET TO BE MODIFIED:
 1=ARRAY SHADING TABLES
 2=ARRAY SPACING
 3=ARRAY SAMPLING RATES
 4=PLOT FORMAT VARIABLES
 5=SOUND VELOCITY
 6=DATE
 7=LIST DEVICE
 8=RETURN TO EXECUTIVE
6
(15 APR 1977)
CHANGE DATE? (Y OR N)
Y
ENTER DATE (12 CHARACTERS MAX.)
16 APR 1977
```

Figure 2.5-7. Sample Date Dialog

```
ENTER DATA SET TO BE MODIFIED:
 1=ARRAY SHADING TABLES
 2=ARRAY SPACING
 3=ARRAY SAMPLING RATES
 4=PLOT FORMAT VARIABLES
 5=SOUND VELOCITY
 6=DATE
 7=LIST DEVICE
 8=RETURN TO EXECUTIVE
7
ENTER LIST DEVICE:  (1=CRT, 6=LP, 12=TTY)
(    1)
6
```

Figure 2.5-8. Sample List Device Dialog

2.7 TIME DOMAIN BEAMFORMING

(U) To start, boot up the computer as for TAP-II and select the "T" option in Executive. However, before attempting to run this program, all switch settings, cabling, and computer I/O cards should be properly set or located, as described in Section 2.1.2. Also, Array Shading Table No. 3 for the array to be used MUST have been set up in EDITING.

(C) The computer will ask for the array type. For the HF array, a fixed sample rate is used and the computer will print the appropriate frequency synthesizer setting, which must then be dialed in. For the LF and MF arrays, there are two choices. The setting the operator selects depends upon the designed frequency range (see Table 2.7-1).

(C) Following the array and sample rate selection, the computer asks for the desired steer angles. These angles are entered in pairs. Each pair must be in the same range; these ranges are printed on the CRT. Up to 16 angles can be entered for LF or MF samples rates, and up to 6 can be entered for the HF sample rate. All inputs are error checked, and the operator is directed to re-input an entry if an error is detected.

(C) Steer angles are entered in integer degrees, in the range from +90 to -90. A carriage return must be entered after each number: $+90^{o}$ is forward, 0^{o} broadside, and -90^{o} aft. The input can be terminated at any time by a 99 entry, if less than the full number of allowable angles is desired.

(U) After the last angle is entered, the computer prints a summary of inputs andautomatically starts the analysis.

(C) 16 analog outputs are provided. The outputs are in the same order as the input list of steer angles. Valid frequency ranges of these outputs are given in Table 2.7-1.

(U) Figures 2.7-1 through 2.7-6 show typical input sequences.

(U) The Time Domain Beamforming process can be stopped at any time by pressing sense-switch 1, and then another set of inputs entered. If 12345 is entered for the array type, the TAP-II Executive will be automatically started.

(U) The Lambda filter switch must be set according to the parameters in Table 2.7-1. All panel switches must be set up per Table 2.1-1.

(U) Time Domain Beamforming uses Array Shading Table No. 3 which must be set up in EDITING for the array to be used before Time Domain Beamforming is selected. Any shading scheme desired may be entered by the operator, although Hanning is normally chosen. The Array Calibration Tables are not used, consequently any bad array element should be zeroed out in the shading table.

TABLE 2.7-1

Time Domain Beamforming Parameters

Array Type	Sample Rate	Frequency Synt. Setting	Lambda Filter Setting	Valid Beamformer Output Frequency Range	Max. No. Beams
LF	LF(53.0 Hz)	90.945 Hz	LF	0 - 20 Hz	16
LF	MF(171.43 Hz)	294.171 KHz	MF	48 - 52 Hz	16
MF	MF(171.43 Hz)	294.171 KHz	MF	0 - 60 Hz	16
	HF(848.0 Hz)	1455.168 KHz	HF	145 - 149 Hz	6
HF	HF(848.0 Hz)	1455.168 KHz	HF	0 - 320 Hz	6

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```
TIME DOMAIN BEAM FORMING PROGRAM
ENTER ARRAY TYPE (1=LF, 1=MF, 3=HF)
1
ENTER SAMPLE RATE (1=LF, 2=MF)
1
```

Figure 2.7-1

```
SYNTHESIZER SETTING  =  9Ø.948 KHZ
ENTER BEAM STEER ANGLES FOR MAXIMUM OF 16 BEAMS
ENTER RETURN AFTER EACH ANGLE
ENTER 99 AFTER LAST ANGLE
STEER ANGLES MUST BE IN PAIRS WITHIN THE FOLLOWING BOUNDARIES
-98 TO -50, -49 TO -1, 0 TO 49, 50 TO 90
48
42
44
46
40
50
ERROR, ANGLE MUST BE IN RANGE 0 TO 49.  RE-ENTER
49
52
54
56
58
60
62
64
66
68
70
```

Figure 2.7-2

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TIME DOMAIN BEAM FORMING PROGRAM

SUMMARY OF ENTERED DATA

ARRAY TYPE: LF

SAMPLE RATE: LF

SYNTHESIZER SETTING: 98.948 KHZ

STEER ANGLES:	48	42
	44	46
	48	49
	52	54
	56	58
	60	62
	64	66
	68	70

TAP-II SHADING TABLE NO. 3 IS USED

SELECT LF FILTERS

ANALOG OUTPUT VALID ONLY OVER 0-20 Hz RANGE

Figure 2.7-3

```
TIME DOMAIN BEAM FORMING PROGRAM

ENTER ARRAY TYPE (1=LF, 2=MF, 3=HF)

2

ENTER SAMPLE RATE (2=MF, 3=HF)

3
```

Figure 2.7-4

```
SYNTHESIZER SETTING= 1455.168 KHz
ENTER BEAM STEER ANGLES FOR MAXIMUM OF  6 BEAMS.
ENTER RETURN AFTER EACH ANGLE
ENTER 99 AFTER LAST ANGLE
STEER ANGLES MUST BE IN PAIRS WITHIN THE FOLLOWING BOUNDARIES:
-98 TO -1, 0 TO 90
-99
-45
0
45
99
```

Figure 2.7-5

TIME DOMAIN BEAM FORMING PROGRAM

SUMMARY OF ENTERED DATA:

ARRAY TYPE: MF

SAMPLE RATE: HF

SYNTHESIZER SETTING: 1455.168 KHz

STEER ANGLES -98 -45

0 45

TAP II SHADING TABLE NO. 3 IS USED

SELECT HF FILTERS

ANALOG OUTPUT VALID ONLY OVER 145-149 Hz RANGE

Figure 2.7-6

2.8 ERROR HALTS

(U) During the operation of the TAP-II software, certain conditions can occur due to operator error or equipment malfunction which make it impossible for the computer to continue to produce meaningful data. Upon detection of an irrevocable error, the computer will halt and display an error code in the S register. The error codes displayed are shown in Table 2.8-1. If an error halt occurs, the operator should analyze the failure, take corrective action, and re-boot the system as described in paragraph 2.2.

(U) Other halts may occur as a result of operator error, such as not readying a magnetic tape unit or trying to beamform at a sample rate different from the calibration sample rate. In these cases, a message is printed on the CRT.

TABLE 2.8-1

Error Halts

Code	Meaning
102001	Operator input error
102002	No input completion interrupt
102003	Disc too slow or sample rate too fast (Check frequency synthesizer setting)
102004	Disc interface delay
102005	Not defined
102006	Disc call error
102007	Storage exceeded
102010	Disc status bad, track in B register
000010	AP error in Time Domain Beamformer (check freq. synth. setting)

2.9 TAPE AND DISC COPYING - SYSTEM BACKUPS

(U) All software for TAP-II is delivered on Disc packs. Backup copies are also provided on magentic tape. Using a program called DLU, which is supplied on paper tape, the backup system copies can be written from magnetic tape to a Disc pack, or additional magnetic tape copies can be made. The procedure to be used is as follows:

(1) Mount the DLU program paper tape in the tape reader and ready the reader.

(2) Read in DLU using the binary loader (put the address of the PTR in the S register and hit PRESET, IBL, RUN).

(3) Put the address of the system CRT in the S register, Z in the P register, and hit RUN.

(4) The computer will ask for the I/O assignment for the Mag Tape unit and the Disc. Answer these questions with the low order I/O card location.

(5) The computer will then ask a series of conversational questions about the copying process to be performed. If the operator wants more detail about any question, a ? can be entered and greater detail will be provided. The user can COPY from Mag Tape to Disc, COPY from Disc to Mag Tape, or VERIFY that a Mag Tape and Disc copy are identical. Many copy files can be on one Mag Tape. The computer simply asks the operator which file is desired, then automatically skips properly. All Mag Tape files have an ID line. When copying to Mag Tape, the computer asks the operator to type in an ID line, which can be any 70-character message. When copying from Mag Tape, the ID line is listed and the operator asked to type in YES or NO to accept the ID as the one desired.

Either the lower or upper disc can be involved in a copy process. The lower disc is 0 (zero), and the upper disc is 1 (one).

2.10 AP-120B DIAGNOSTICS

(U) A special disc labeled "AP-120B Software Support" has been set up to simplify the running of AP diagnostics. A Summary Procedure for running these diagnostics is given in Table 2.10-1.

(U) More detailed explanations of the various diagnostics may be found in the Diagnostic Software Manual published by Floating Point Systems, which was delivered with TAP-II.

TABLE 2.10-1.

Brief Summary Of Stand-Alone AP-120B Array Transformer Processor Diagnostic's

1. Mount AP-120B software support disc in upper drive.

2. Boot system using $41201_{(8)}$ in S register.

3. The first test to be run is APTST. This program exercises the panel and DMA interface functions of the AP-120B. It tests all of the available memory inside the AP-120B with simple patterns and then with pseudo-random number patterns.

4. The diagnostic is run as follows:

   Reset (clear) SS #14 on CPU switch register.

   Type: "5", "CR"

   "RWE", "CR", "LF"

   Diagnostic is now running. After approximately 3 minutes 10 seconds, the computer will print a "P" on the display. This denotes a completed pass. Any other printout, the operator is directed to the Diagnostic Software Manual.

TABLE 2.10-1 (Continued)

5. Repeat step 2 (re-boot the system).

6. The second test to be run is APPATH. This program tests the bulk of the internal data paths within the AP-120B. In contrast to the paths and registers tested by the program APTST, the data paths and and registers tested by the APPATH require the execution of AP-120B micro-instructions. Thus, this test also effectively checks most of the AP-120B micro-instruction set.

7. The diagnostic is run as follows:

   Reset (clear) SS #14 on CPU switch register

   Type: "1", "CR"

   "RWE", "CR", "LF"

   Diagnostic is now running. After approximately 2 minutes 5 seconds, the computer will print a "P" on the display. This denotes a completed pass. Any other printout, the operator is directed to the Diagnostic Software Manual.

8. Repeat step 2 (re-boot the system).

9. The third test to be run is APARTH. This program exercises and verifies the accuracy of the arithmetic hardware in the AP-120B (FA, FM, and S-PAD). In addition, due to the heavy use of Data Pad and S-PAD registers, the functioning of these registers is thoroughly tested.

   The program utilizes a pseudo-random number generator to produce arguements for Data Pad and S-PAD, to select DPA and the Decimate shift count, and also to select combinations of Floating Adder and S-PAD operations, Data Pad and Write Indices, and S-PAD register addresses which are combined into micro-instructions for the AP-120B to execute.

TABLE 2.10-1 (Continued)

10. The diagnostic is run as follows:

    Reset (clear) SS #14 on CPU switch register

    Type: "2", "CR"

    "RWE", "CR", "LF"

    Diagnostic is now running. After approximately 2 seconds, the computer will print a "A" on the display. This denotes a completed pass. Any other printout, the operator is directed to the Diagnostic Software Manual.

11. Repeat step 2 (re-boot system).

12. The fourth test to be run is FIFFT. This program is intended primarily for use as a verification test of the AP-120B. It does not provide board level diagnostic indicators. The test is based on the fact that a Forward Fourier Transform of a data set followed by an inverse Fourier Transform of the result of the forward transform should result in the original data set within a predictable error limit.

13. The diagnostic is run as follows:

    Reset (clear) SS #14 on CPU switch register

    Type: "8", "CR"

    "R", "CR"

    "P", "CR"

    "1000", "CR"

    "M", "CR"

    "20000", "CR"

    "WE", "CR", "LF"

    Diagnostic is now running. After approximately 1 second, the computer will print a "A" on the display. This denotes a completed pass. Any other printout, the operator is directed to the Diagnostic Software Manual.

Section 3

TIME DOMAIN BEAMFORMING

3.1 THEORETICAL APPROACH AND OPERATIONAL CHARACTERISTICS

(C) Figure 3.1-1A shows the data flow for the time domain beamforming mode. All data paths are identical to those used for the frequency domain mode, with the exception of the output D/A conversion. At the input, 64 analog hydrophone outputs coming from the Lambda amplifiers (and through the NUC sample-and-hold amplifier bank) are multiplexed and digitized by the TAP-II multiplexer. The digitized data is inputted to the TAP-II 21-MX computer and passed straight through to the AP-120B array processor. The AP-120B forms the digital beam samples from the digital hydrophone samples; the beam samples are then transmitted through the 21-MX computer to an output bank of 16 D/A converters. The final output is (up to) 16 continuous broadband analog beams.

(U) All actual computation in this process is performed by the AP-120B processor. The computer simply acts as a data transfer device. For clarity, Figure 3.1-1a shows two data paths between the AP-120B and the 21-MX. In actuality, there is only one bidirectional interface.

(U) Figure 3.1-2 shows a diagram of the computational process within the AP-120B. Data is transferred to this processor as groups of 64 simultaneous hydrophone samples; one sample from each of the 64 hydrophones from a uniformly spaced Lambda line array. In topology, the beamformer is simply of the conventional delay and sum type, with each hydrophone successively delayed and added to a summed beam. Since the acoustic array is uniformly spaced, for any specific direction only one value of time delay (D) is required, with the first hydrophone requiring a delay of 63D, the second 62D, etc.

(U) Since the samples are in digital form, a digital delay is required. TAP-II forms true digital delays, using recursive digital filters. This

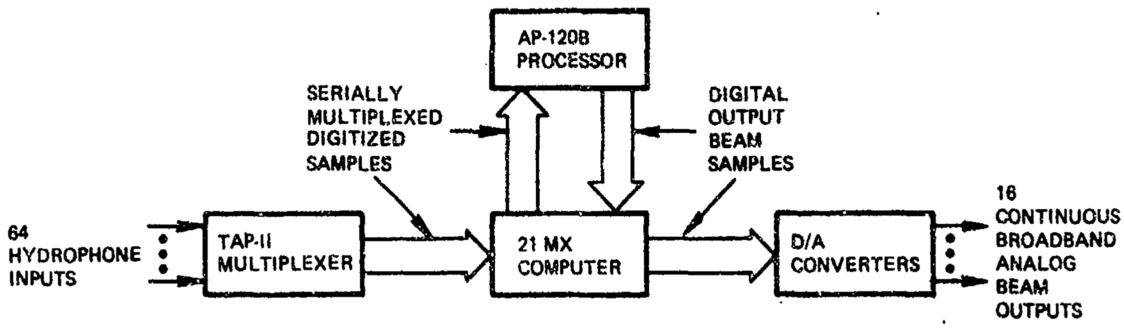

Figure 3.1-1a. Time Domain Beamforming Data Flow

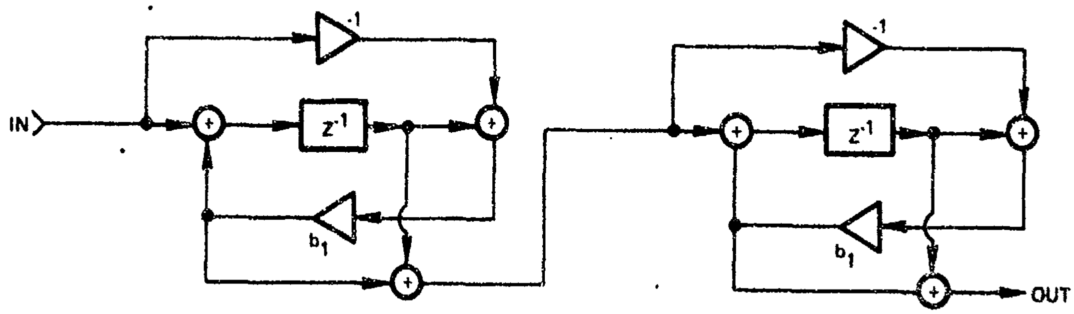

Figure 3.1-1b. Digital Beamforming Time Delay (ϕ_1 Operation)

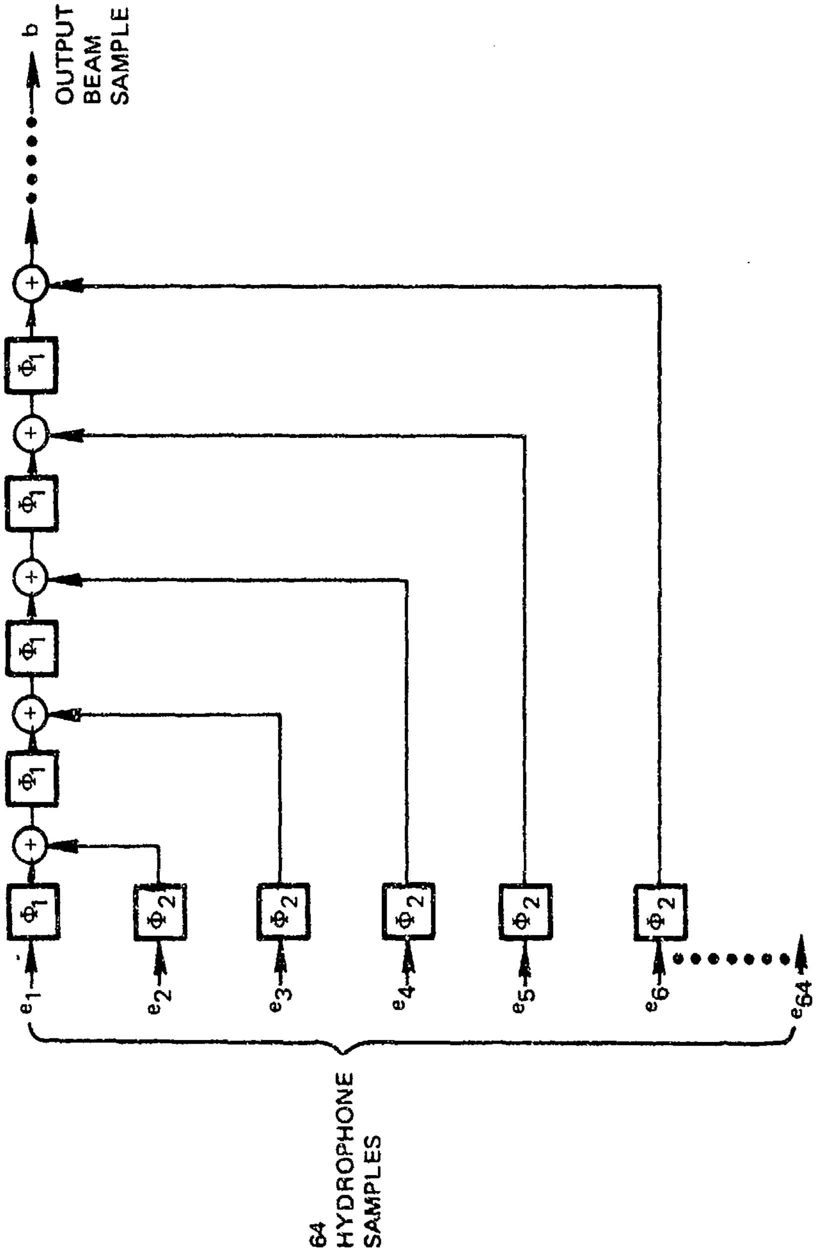

Figure 3.1-2. Time Domain Beamforming Topology

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is an entirely different approach from the common technique of over-sampling, and then delaying by simply picking the sample that lies nearest the proper delayed value. Using a true digital filter to form the delay allows a lower sample rate, and also provides a beam pattern that approaches the theoretical, both for the mainlobe and sidelobes.

(U) The digital filters are formed by the elements ϕ_1 and ϕ_2 in Figure 3.1-2. ϕ_2 is a one-stage delay, in increments of the input sample rate (a one-stage shift register). ϕ_1 is a second order all-pass digital filter. The topology of this filter is shown in Figure 3.1-1b. The combination of ϕ_1 and ϕ_2 forms a true digital delay, with the output of the delay operation being a computed value of the properly delayed sample.

(C) Limitations of this technique are that the digital filters act as true time delays only over a specific frequency band. Outside this band, the delay begins to vary with frequency; consequently, the beam steer angle changes. TAP-II uses five sets of beamformer constants for the three Lambda arrays. Three of the sets cover the Lambda arrays from dc to the array aliasing frequency (one set for each of the three arrays). The fourth set is for the LF array in its aliased region in the range of 48 to 52 Hz, and the fifth set is for the MF array in its aliased region, from 145 to 149 Hz. The beamformer acts in only one of these five modes at any one time, and forms up to 16 continuous beams at the LF or MF sample rates, or six beams at the HF sample rate. Beams can be steered at any angle from -90 to +90 degrees, in 1 degree increments.

(U) Beam steer angles depend upon the b_i constants shown in Figure 3.1-1b. Tables of these constants are stored on disc for all steer angles for each of the five operational modes. When an operator selects the array and frequency range desired, together with the desired steer angles, the 21-MX computer pulls the required constants from disc and sends them to the AP-120B. The continuous beamforming mode is then automatically started and continuous until the operator interrupts the process.

(U) Table 2.7-1 (shown in Section 2.7) lists the five modes of beamformer operation, and gives the operational parameters for each.

(U) The analog outputs from the D/A converters are continuous, and broadband. Narrowband spectral analysis of these signals can be performed by any conventional spectrum analyzer, at any frequency within the ranges tabulated in Table 2.7-1. Spectral analysis should not be done outside the indicated ranges, because the beam steer angles are not correct, and higher harmonics of the sampling process exist.

(C) Within the frequency ranges given in Table 2.7-1, the digital time delays are stable and accurate, with beam steer angle errors versus frequency being less than a beamwidth. Figure 3.1-3 plots the steer angle errors versus frequency (in terms of beamwidth) for the three modes in which the frequency coverage is from dc to the array cutoff frequency (20 Hz for the LF array, 53 Hz for the MF array, and 320 Hz for the HF array).

(U) Any array shading taper desired can be utilized in the time domain beamforming mode. TAP-II Shading Table No. 3 is used to weight all hydrophone samples, in the first computational step. The TAP-II Shading Table is set up by the operator, in the editing mode, before the time-domain beamforming is started.

(U) Time domain beamforming is an enhancement of TAP-II's capabilities, added during Phase II of the development. The only new hardware required was the output D/A converters, and the associated computer interface. The hardware is described in Section 3.2. Documentation for the software is given in Appendix A. Program listings are in the TAP-II program listing package.

3.2 D/A CONVERTER HARDWARE

(U) Figure 3.1-4 shows a block diagram of the D/A converter system. Sixteen channels of output are provided in two independent eight-channel

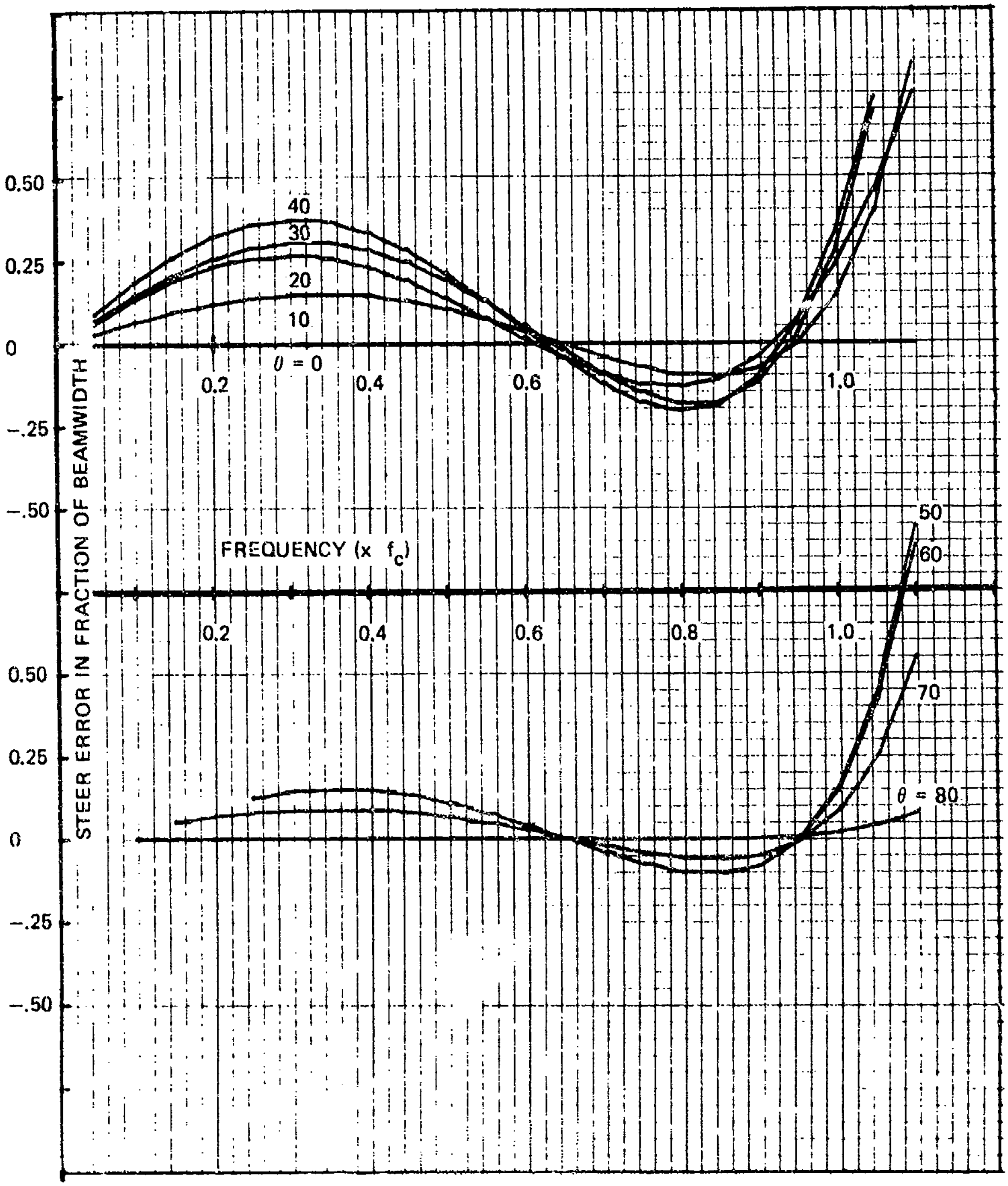

Figure 3.1-3. Time Domain Beamsteer Errors

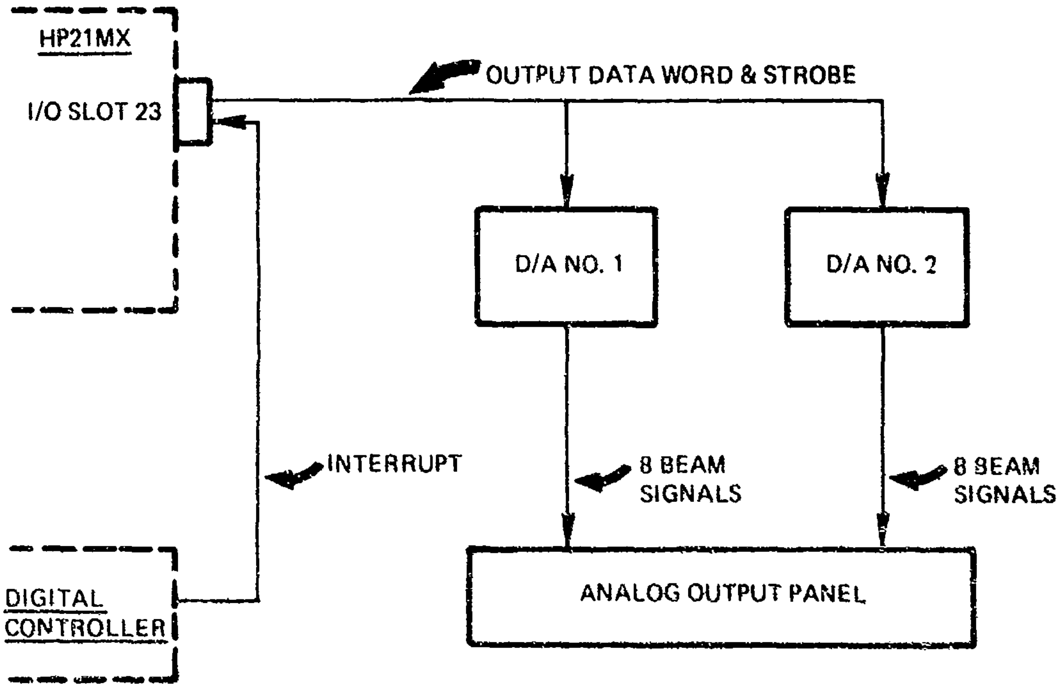

Figure 3.1-4. Block Diagram of the D/A Converter System

chassis. A timing interrupt is derived from the received data digital clock in the Digital Controller to initiate uniformly spaced analog output transitions at the sample rate.

(U) Each beam formed is assigned to a D/A output channel which presents an analog voltage of up to ±10 volts to the analog processing devices at the analog output panel.

(U) The D/A interface card is a standard microcircuit interface card, Hewlett Pachard part No. 12566. The jumper options are positioned as shown below:

Jumper	Position
W1	A1
W2	B2
W3	A1
W4	B2
W5, W6, W7, W8	Connected
W9	A1

(U) This card is mounted in I/O channel 23 in the 21-MX computer. Digital information is transferred from the computer interface card to the D/A converters using the 16 output data lines for data and addressing, and the device command line for a strobe. The output data word format is shown below:

Data Word Bits	Function
Bits 15 - 4	2's complement output data word. Bit 15 is MSB.
Bit 3	D/A unit select - 0 selects D/A No. 1, 1 selects D/A No 2.
Bit 2 - 0	Channel 1 - 8 select.

(U) The device flag input on the interface card is used as a timing interrupt. It is derived from a delayed frame pulse generated in the Digital Controller.

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(U) Detailed interface card I/O cable informatio. · round on Drawing EO 4200708, Revision C.

(U) The digital-to-analog converters used are Datel, Part No. DDS-32-8-12B-C-4. The jumper options listed below should be installed at installation:

D/A No. 2 - On card I/O-2 (Drawing 10180): Use jumper J1

D/A No. 1 - On card I/O-2 (Drawing 10180): Use jumper J1, omit jumper J5, use jumpers J2, J3, and J4.

(U) These jumper options provide termination pull-up voltage and invert the select bit for dual system use.

Applicable Drawings

Document Number	Title
Datel MDABM01401	System 256, Data Distribution Instruction Manual
BR E04200702, Rev. B	DG Controller Logic Drawings
BR E04200706, Rev. D	W/L Analysis Sync Circuits
BR E04200708, Rev. B	W/L I/O Cables
BR E04200708, Rev.	W/L I/O Cagles
BR 4200726	Analog Output Panel

APPENDIX A

TIME DOMAIN BEAMFORMING SOFTWARE

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PROGRAM: (C) TIME DOMAIN BEAMFORMING MAIN PROGRAM, TDBFM

1. FUNCTION. (C) TDBFM collects data from the Digital Controller, passes it to the Array Processor, retrieves the results from the Array Processor, and sends them to the D/A converters.

2. CONSTRAINTS. (U) None

3. CALLING SEQUENCE. (U) N/A

4. DESCRIPTION OF INPUT. (U) Input is the Digital Controller data, as described in Figure 4.5.4-1, with header data suppressed.

5. DESCRIPTION OF OUTPUT. (C) Output is bursts of data for up to 16 D/A channels. Output rate is determined by sample rate, one burst per minor frame.

6. FILES USED. (C) The shading tables on the TAP II common track are read by TDBFI.

7. ERRORS. (U) None

8. COMPUTER OPERATOR INSTRUCTIONS. (U) N/A

9. DESCRIPTION OF PROCESSING. (C) Processing steps are keyed to the flowchart, Figure A-1 TDBFM receives control from the TAP II Executive by reading in core load 7.

(1) (C) The I/O system is initialized by disabling the interrupt system and resetting all I/O channels. TDBFI is called to perform the operator question and answer sequence, send table data to the AP-120, and start the AP program. Once this is done, the AP program runs continuously and waits for TDBFM to send it data.

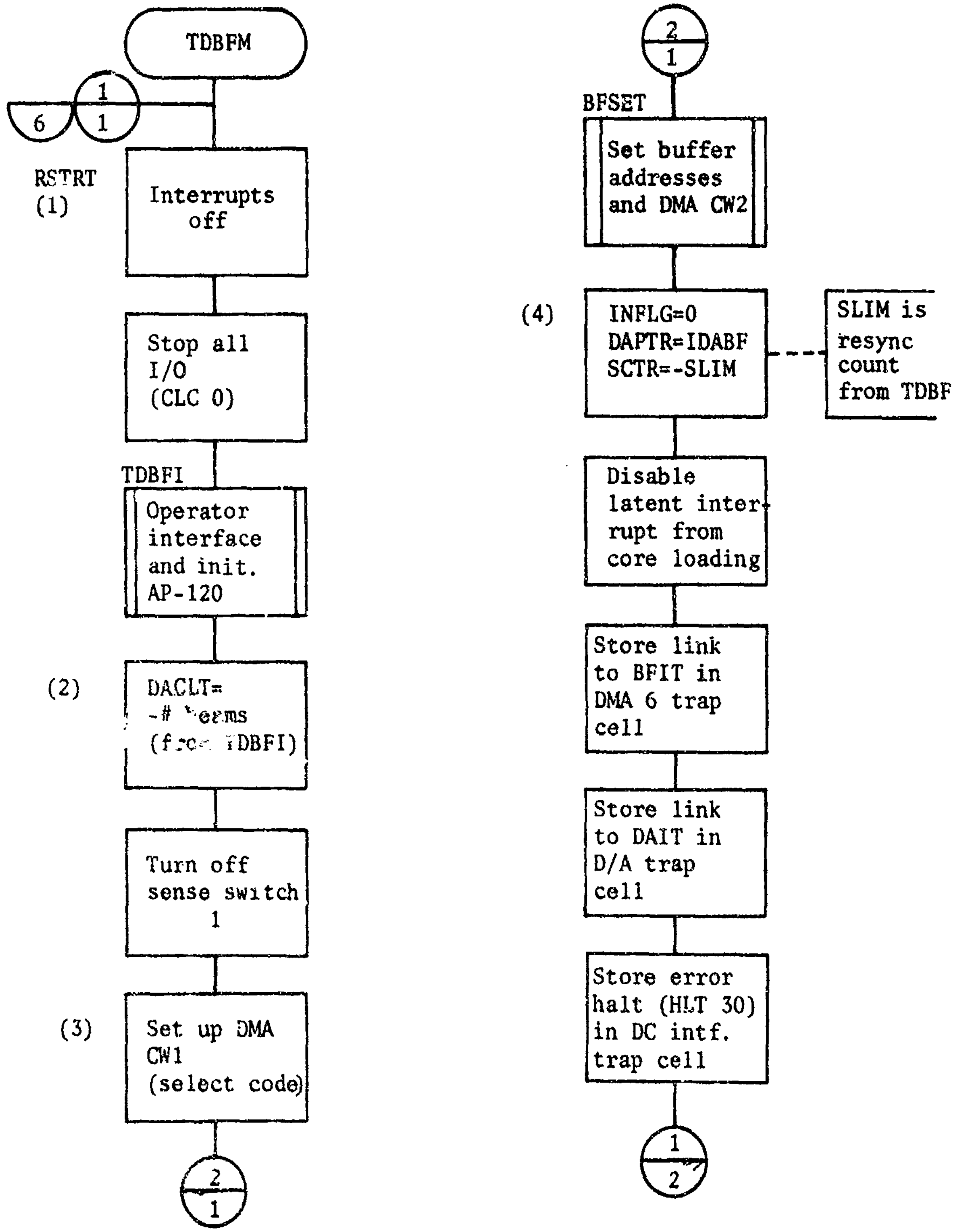


Figure A-1. TDBFM (Sheet 1 of 13)

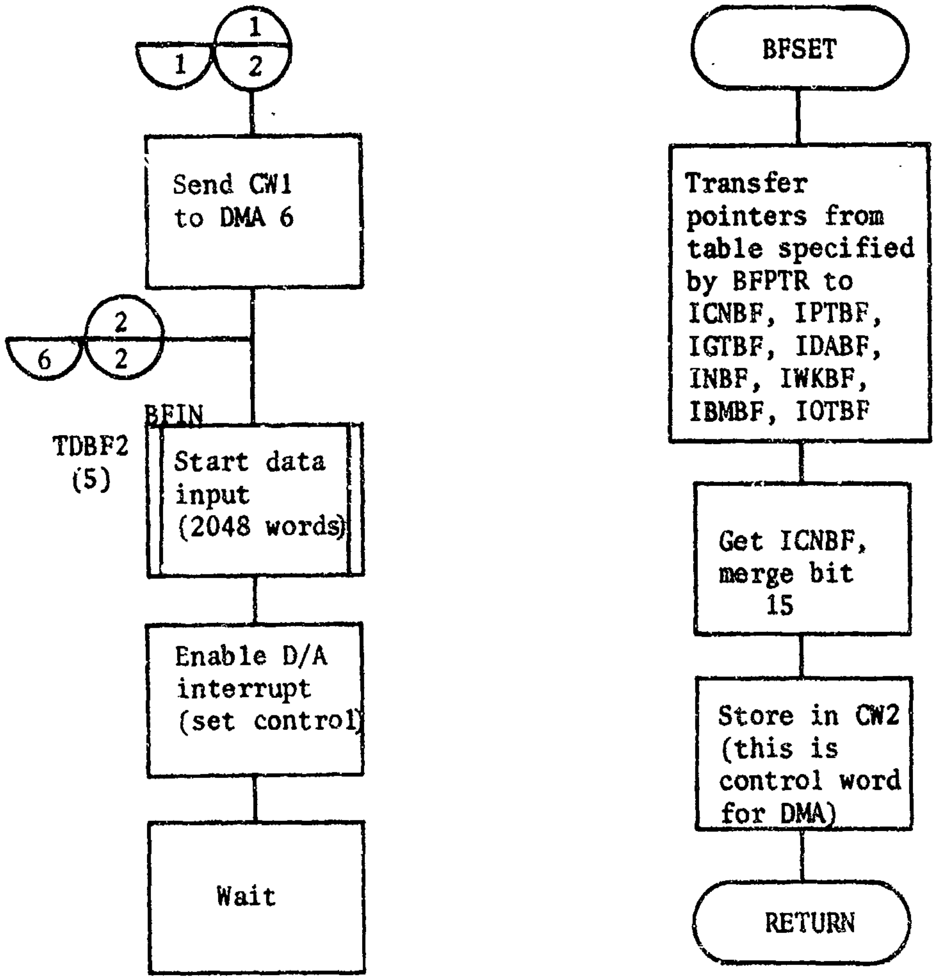
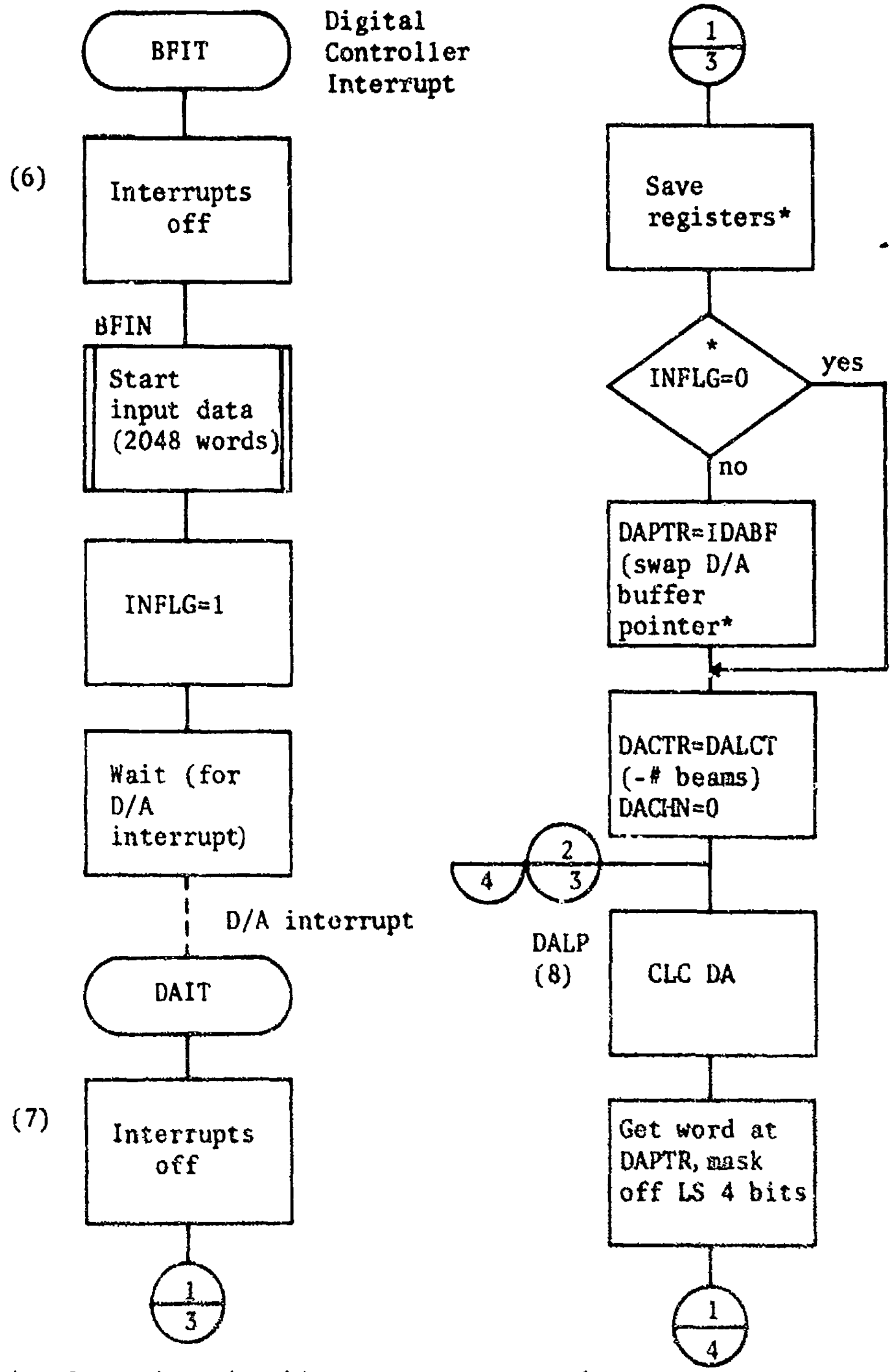


Figure A-1. TDBFM (Sheet 2 of 13)



* = Operations in this area are arranged so that the execution times for all paths are identical.

Figure A-1. TDBFM (Sheet 3 of 13)

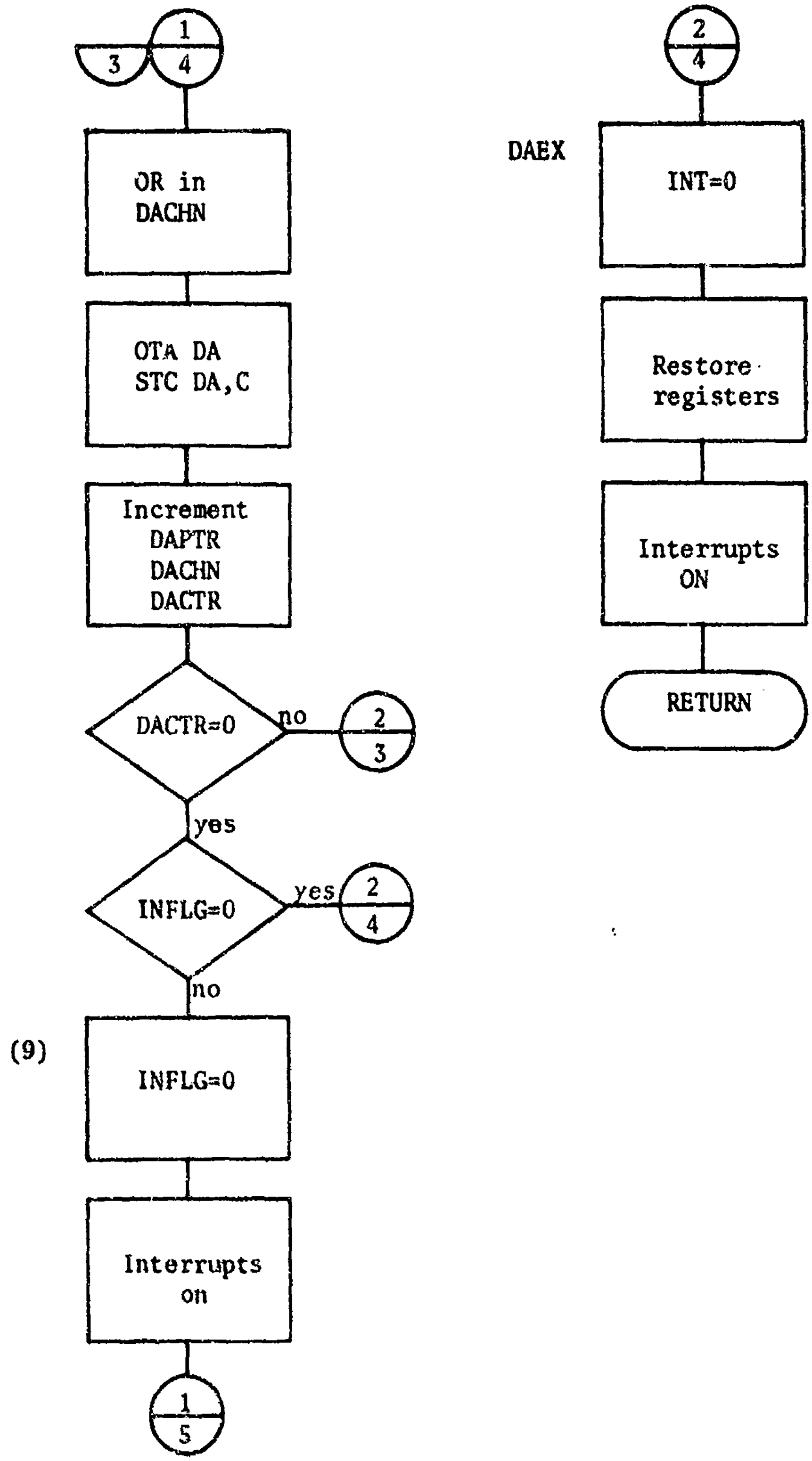


Figure A-1. TDBFM (Sheet 4 of 13)

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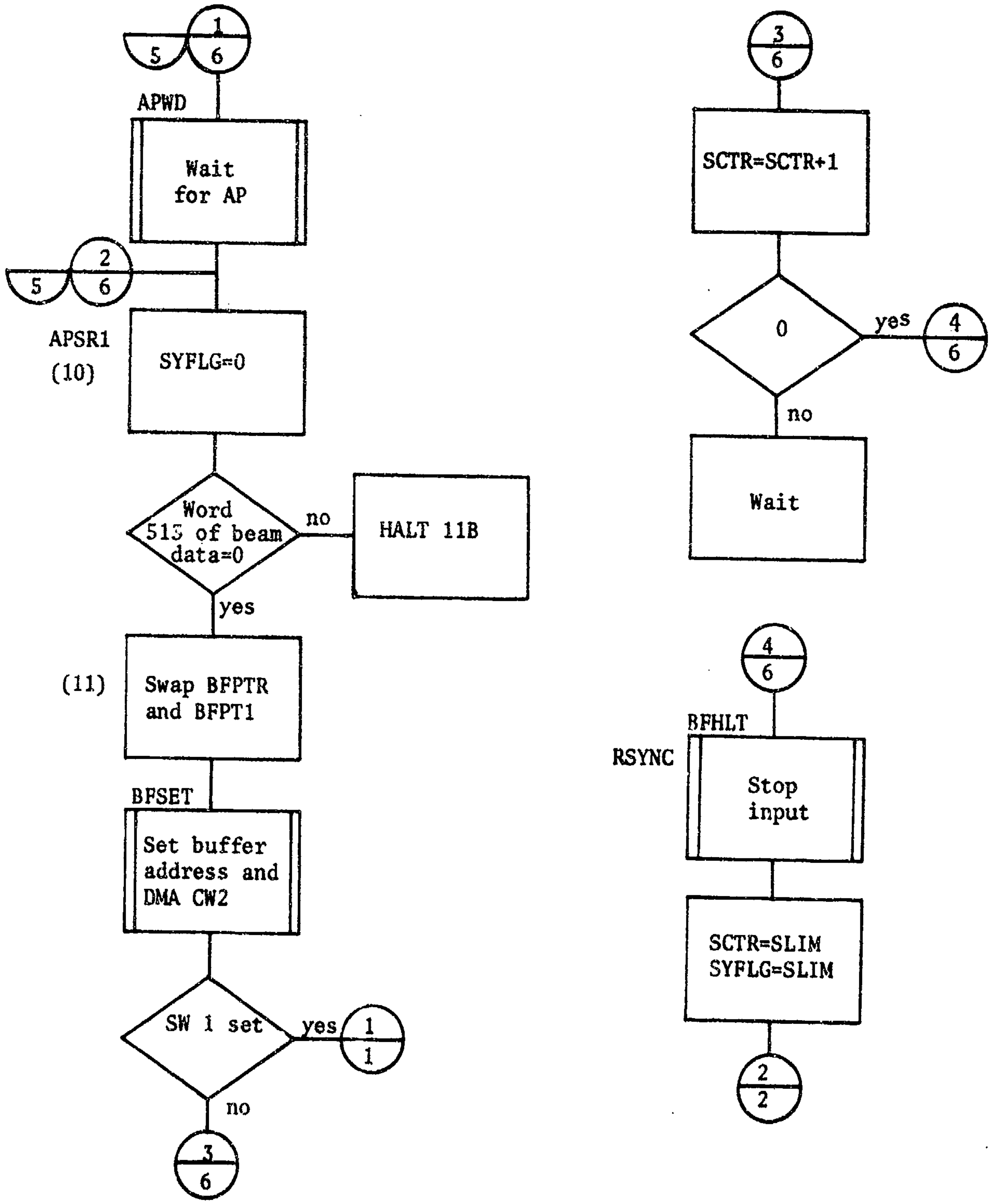

Figure A-1. TDBFM (Sheet 5 of 13)

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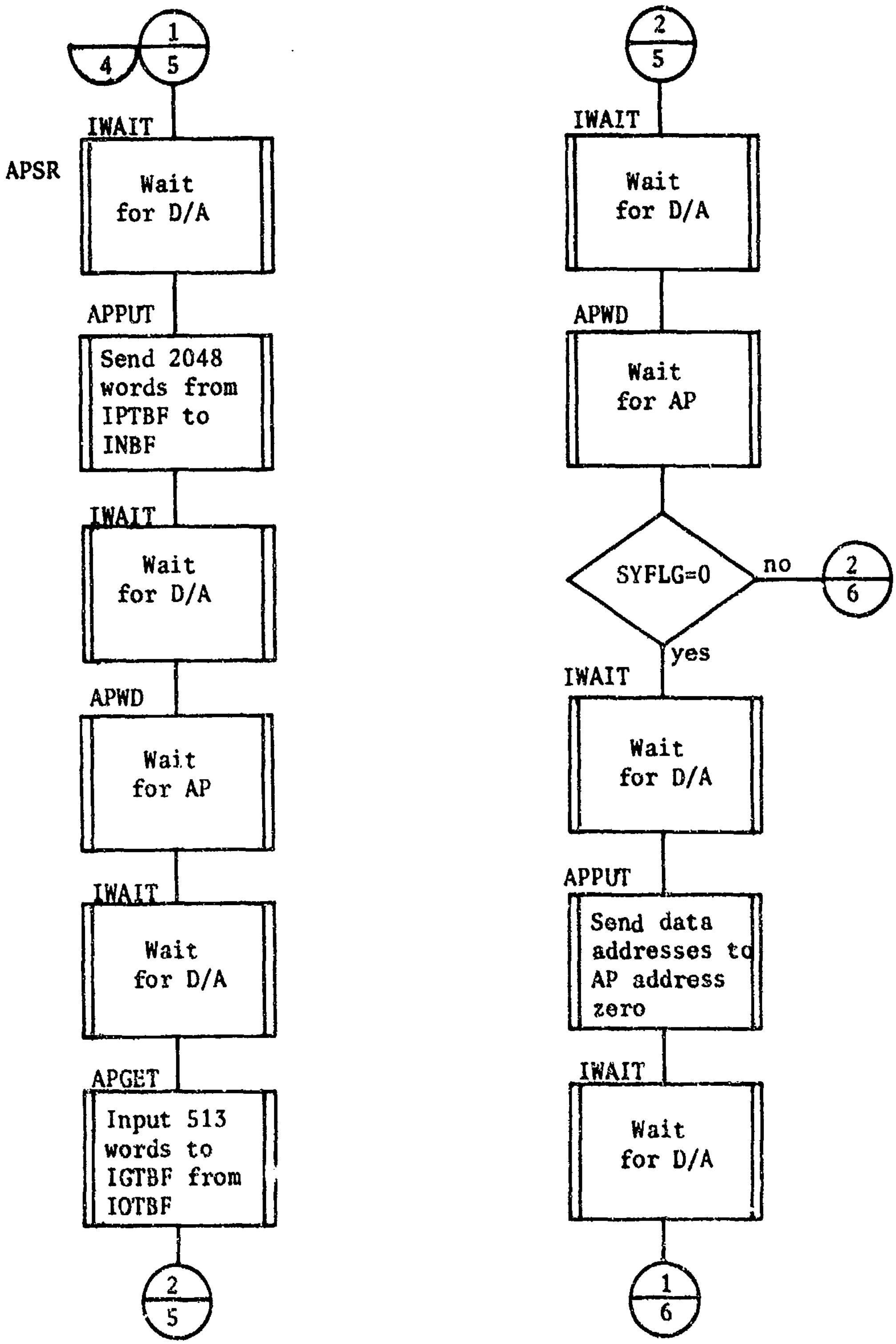

Figure A-1. TDBFM (Sheet 6 of 13)

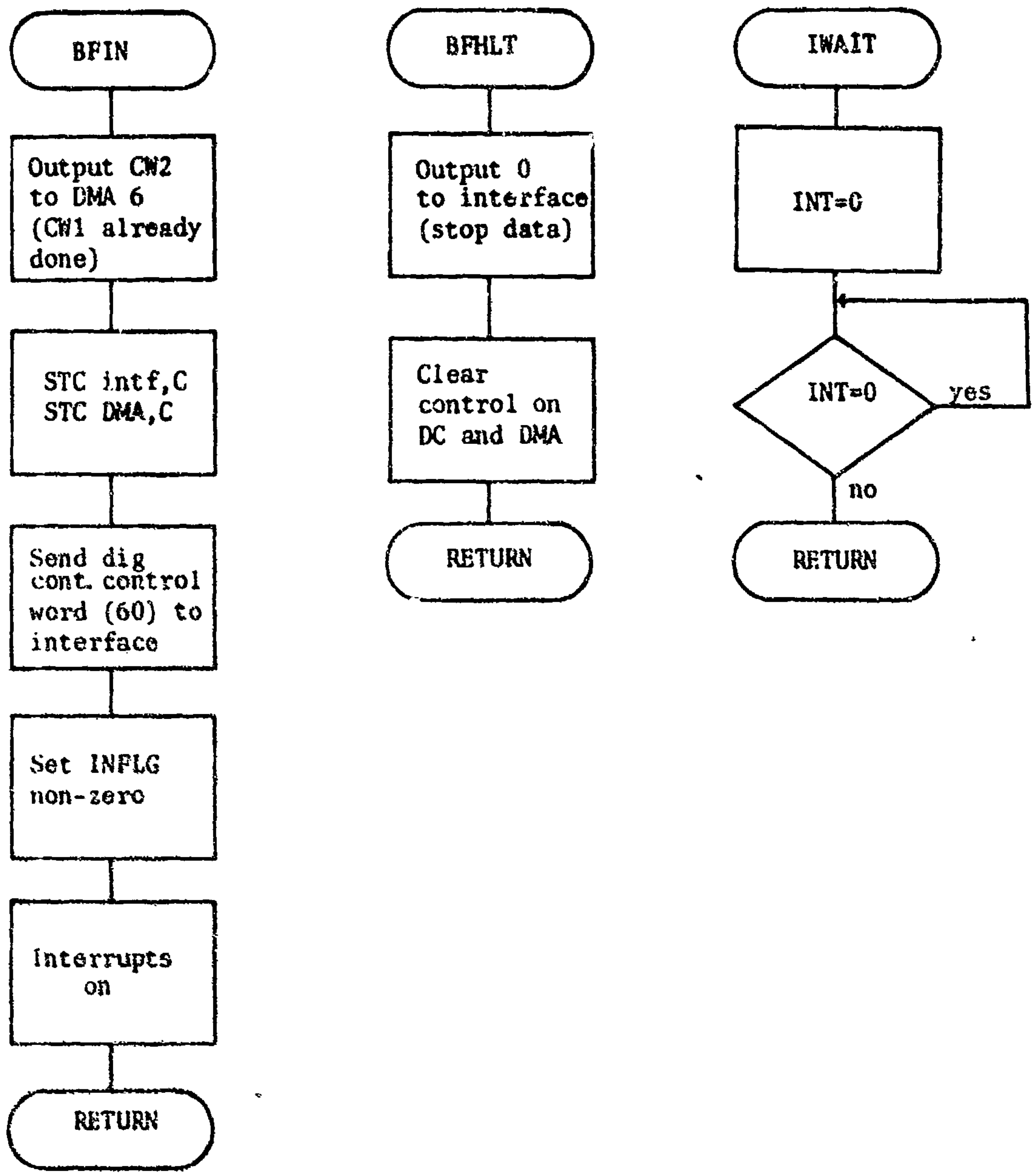

Figure A-1. TDBFM (Sheet 7 of 13)

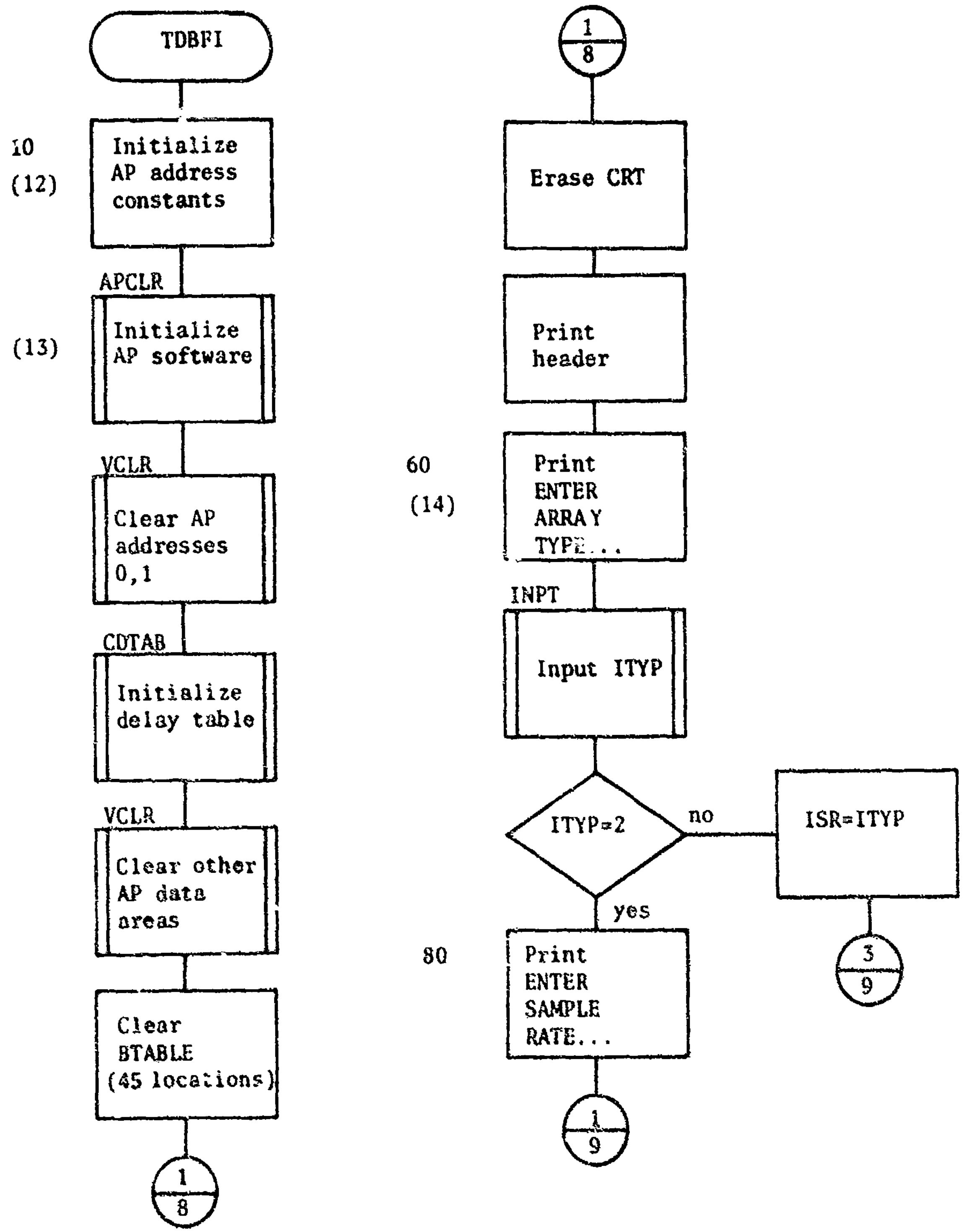

Figure A-1. TDBFM (Sheet 8 of 13)

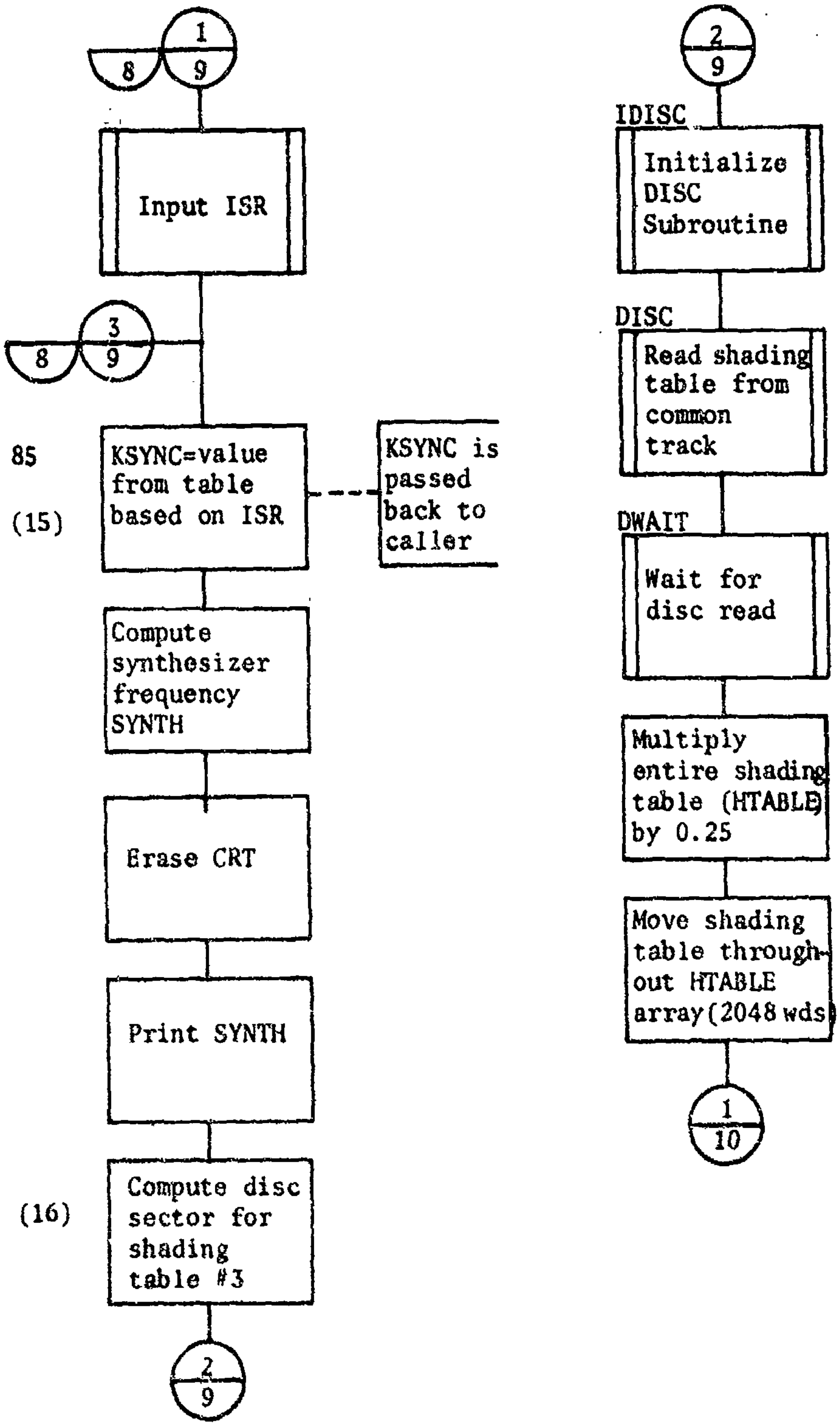

Figure A-1. TDBFM (Sheet 9 of 13)

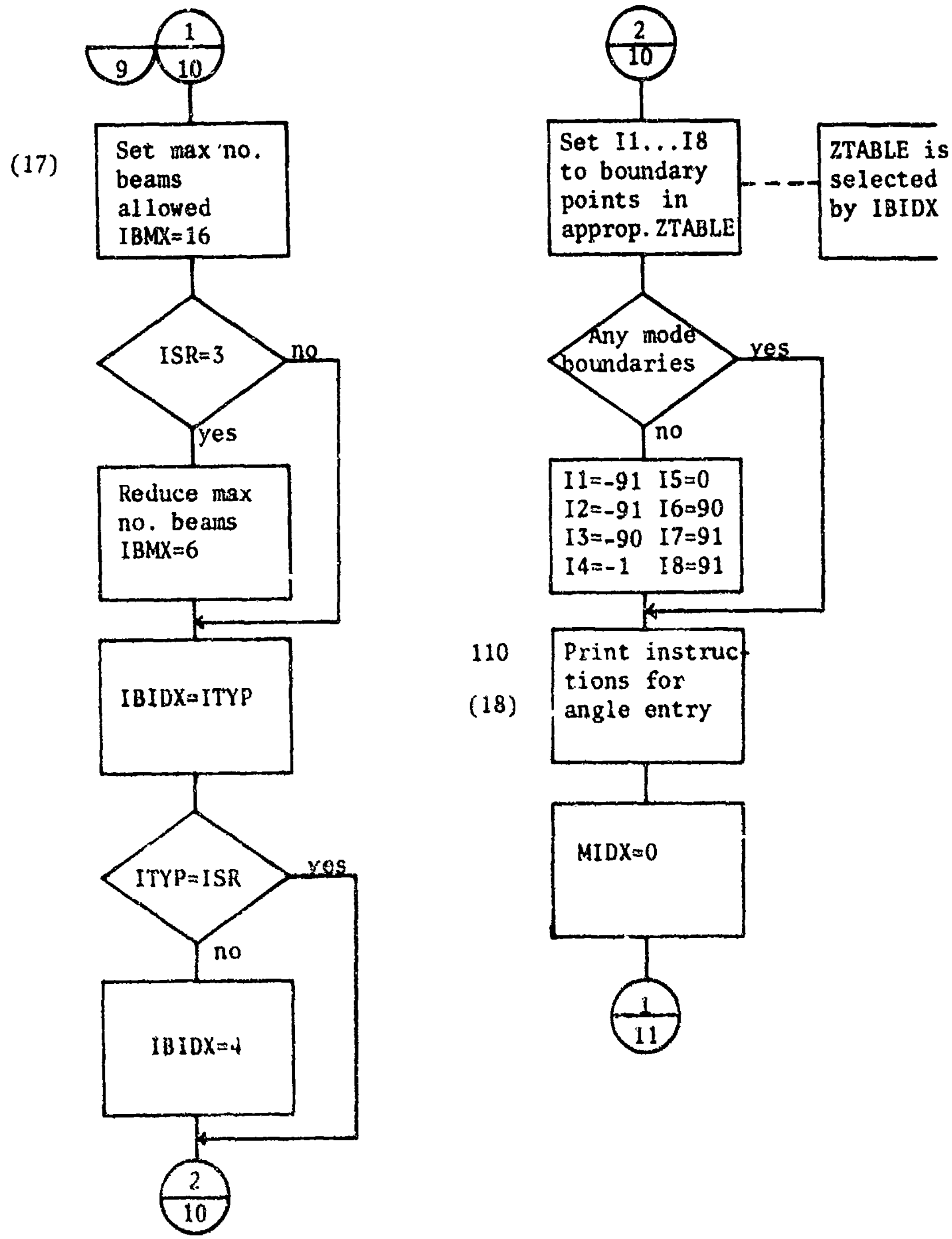

Figure A-1. TDBFM (Sheet 10 of 13)

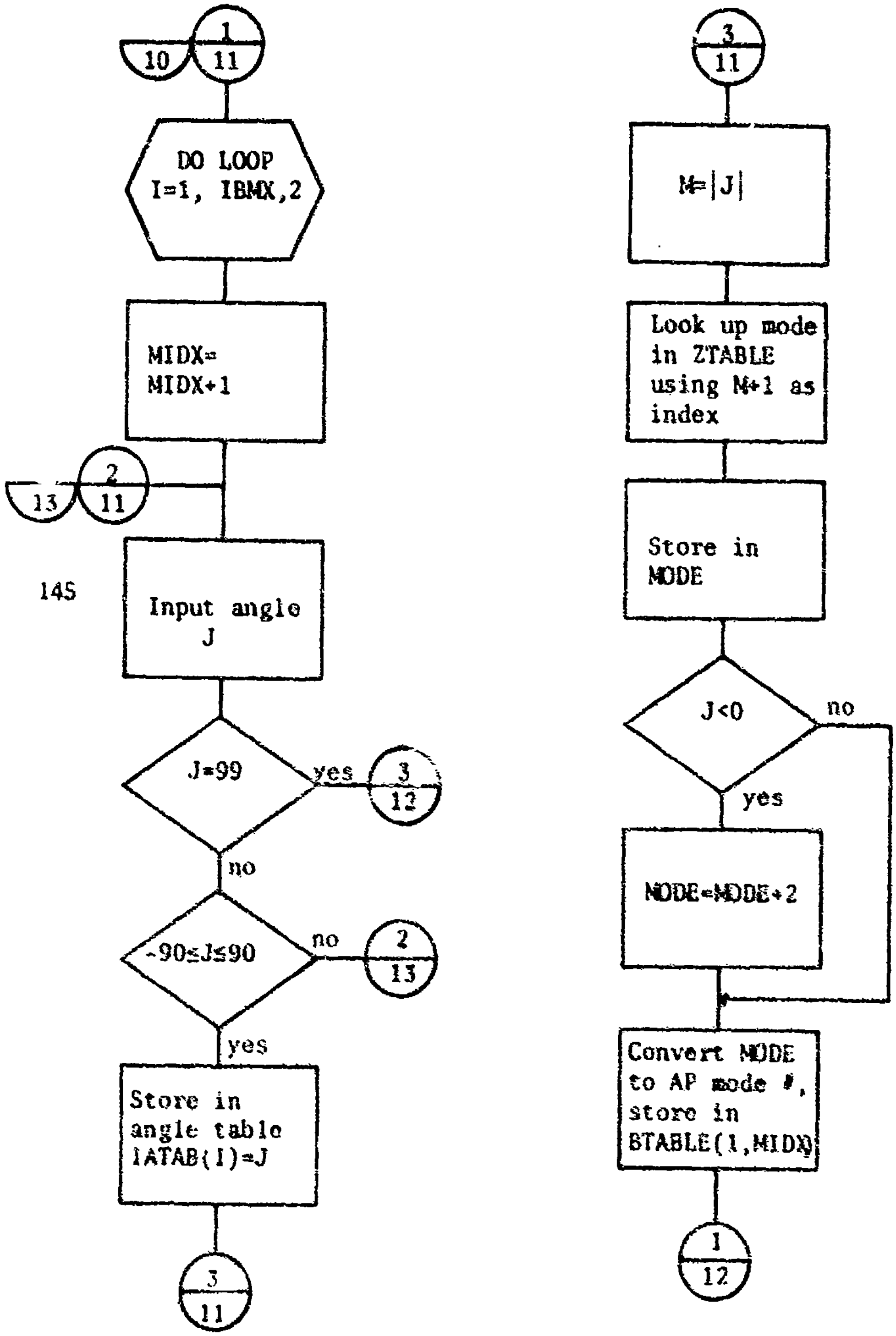

Figure A-1. TD3FM (Sheet 11 of 13)

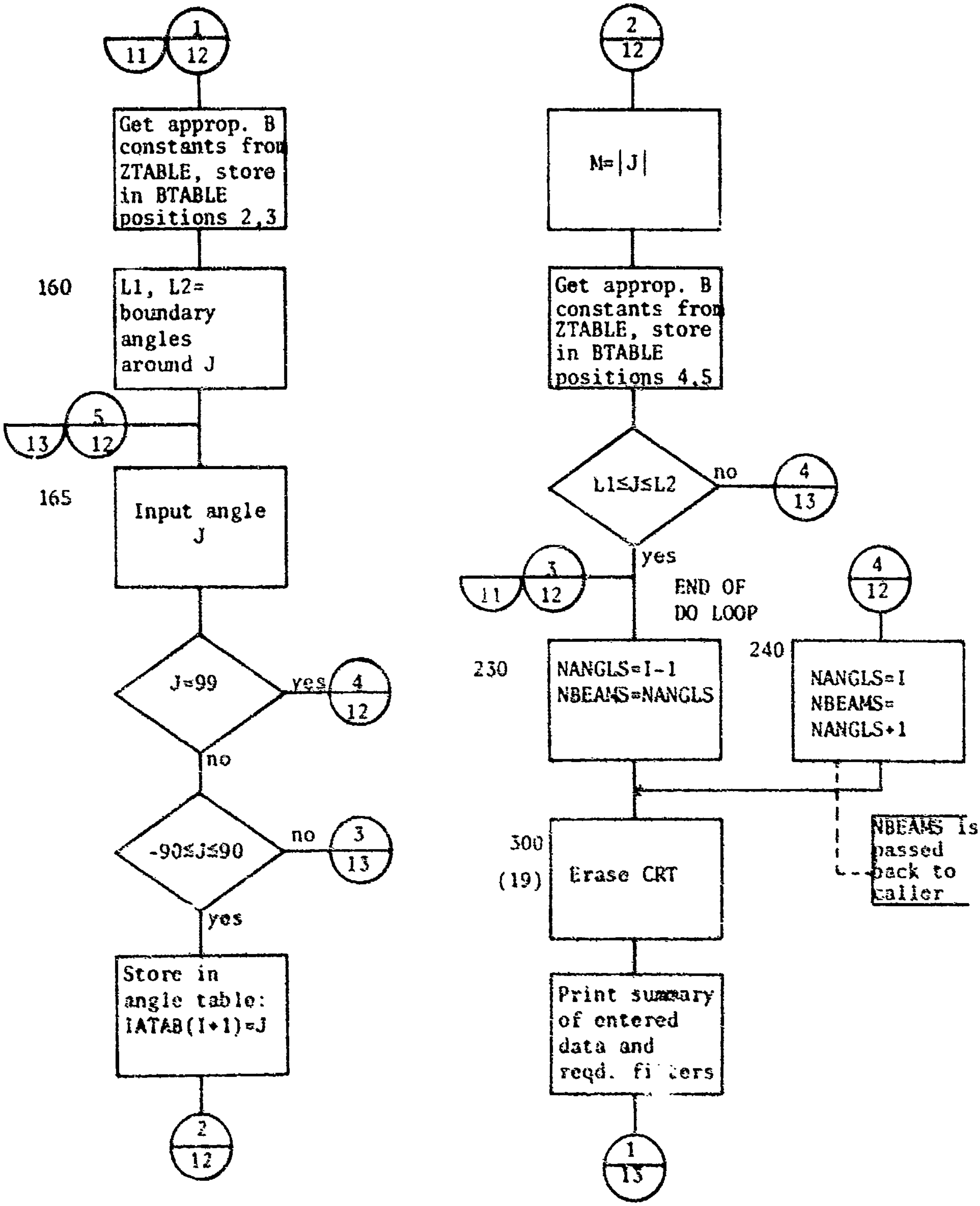

Figure A-1. TDBFM (Sheet 12 of 13)

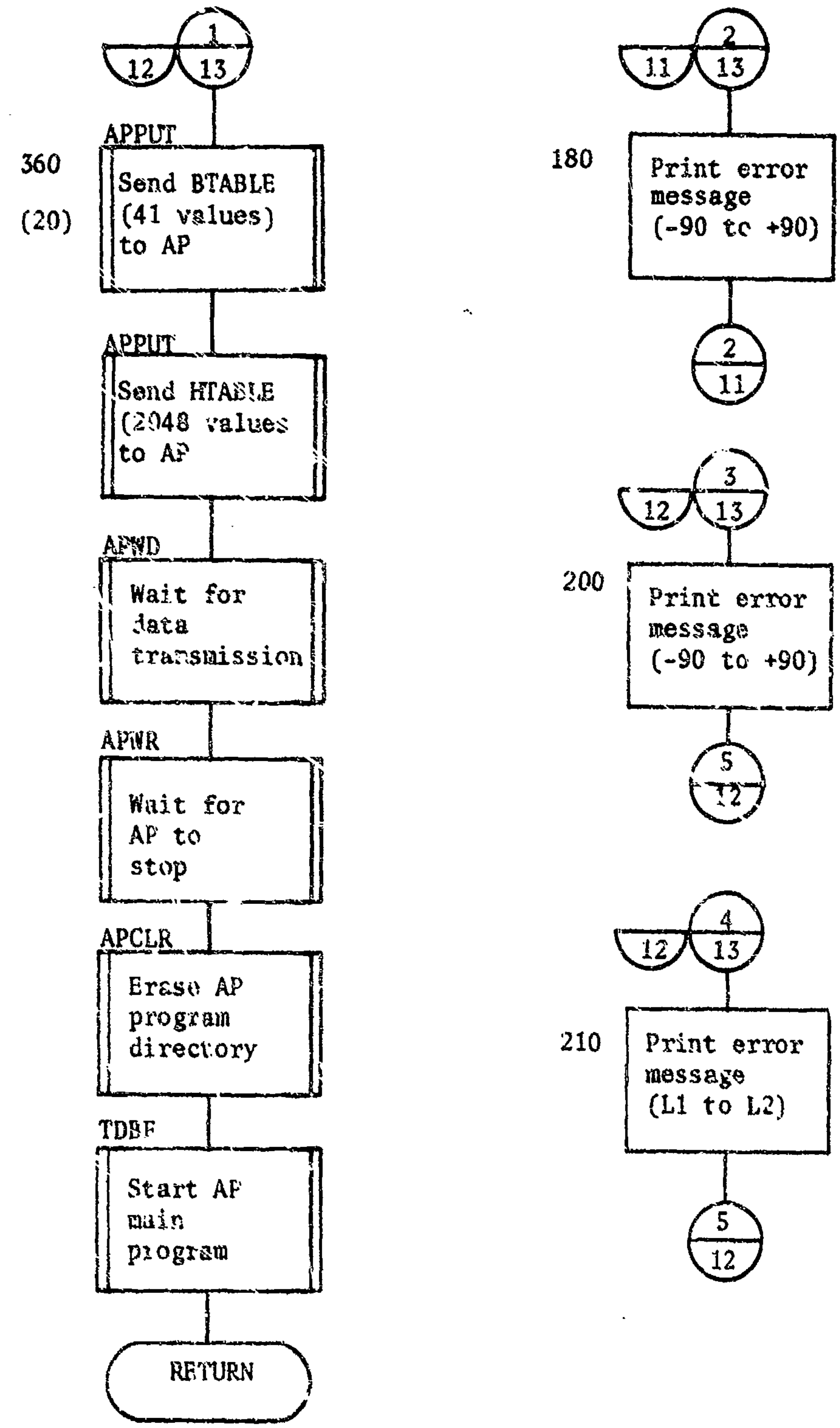

Figure A-1. TDBFM (Sheet 13 of 13)

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(2) (C) Two parameters are returned from TDBFI: DALCT and SLIM. DALCT is the number of beams being processed, rounded up to the next even number. This is required because the AP program only produces an even number of results. TDBFM complements this number and stores it back in DALCT. SLIM is the number of 2048-word input buffers which will be processed in 3 minutes. This will be used to regulate the resynchronizing operation. Sense switch 1 is turned off.

(3) (C) DMA is partially set up for input. This consists of setting up control word 1 (CW1) and storing it in location CW1. This is done here because there is not sufficient time in the input routine to accomplish this later. BFSET is called to set up buffer pointers. BFSET also computes DMA control word 2 (CW2) based on the input buffer address, and stores it in location CW2 for use by BFIN.

(4) (C) Various other switches, counters, and pointers are set, as can be seen from the flowchart. Interrupt links are set up in the proper trap cells. CW1 is sent to DMA channel 6. This is the only time this is done, again because of insufficient time in the input routine. It stays in the CW1 register and does not have to be done at the start of each new DMA cycle. DMA channel 6 is used exclusively for Digital Controller input and channel 7 is used exclusively for AP-120 communication. This choice was made because 6 has higher priority and otherwise the AP might steal every cycle.

(5) (C) BFIN is called to start input of a 2048-word buffer from the Digital Controller. A set control, clear flag is performed upon the D/A interface to enable the once-per-minor-frame interrupts which start the D/A output sequence. The program now waits for interrupts. A D/A interrupt will

transfer control to DAIT. A Digital Controller interrupt (DMA completion) will transfer control to BFIT.

(6) (C) BFIT turns off the interrupt system, calls BFIN to start a new (continuation) DMA input transfer, sets INFLG=1 to trigger AP data transfers and switching of buffer addresses, then waits for interrupts. The next interrupt occurring will be a D/A interrupt, because 32 D/A interrupts will occur for each Digital Controller interrupt. Two important timing items should be noted here. From the occurrence of the DMA interrupt, only 3 word times are allowed before the new DMA transfer must be started, or else there will be loss of sync. Secondly, BFIT must be waiting for the D/A interrupt when it occurs, or else the timing from D/A interrupt until output of D/A data will be irregular. For these reasons, the amount of processing in this area is extremely limited.

(7) (C) DAIT (D/A interrupt processor) first disables interrupts. It then saves all registers. However, the usual "cookbook" method of saving registers is not used because it would result in a variance of timing depending on the state of the overflow register. As described earlier, the timing from the time of interrupt up to the time of output of the D/A data must be invariant. The next step, setting DAPTR to the start of the appropriate output buffer if and only if INFLG≠0, also has some dummy instructions in it for the same reason. DALCT is stored into DACTR. This is the number of beams to be output, and may be one greater than the number of angles specified by the operator. This is due to the fact that the AP program only processes pairs of beams. DACHN is set to zero.

(8) (C) When the D/A interrupt occurred, the device command line was still true from the last pass through DAIT. Therefore, it must be reset by a CLC command. DAPTR points to the current output word. That word is fetched, the LS 4 bits are removed and DACHN merged in their place. This provides a 2's complement number in bits 15-4 with the channel number (0-15) in bits 3-0. This is output to the D/A converters and an STC command is issued to strobe the data into D/A converters. DAPTR, DACHN, and DACTR are incremented. If DACTR is not zero, all beams have not been output, so control is passed back to DALP (the beginning of this paragraph). This continues with increasing channel numbers and incremented data pointer until DACTR reaches zero. At this point, the control FF is still set and will remain set until the next D/A interrupt to allow that interrupt to occur. INFLG is checked. If zero, a new Digital Controller buffer has not been started, so INT is set to zero, registers are restored, interrupts are enabled, and control is returned to the point of interruption.

(9) (C) If INFLG is not zero, a new Digital Controller buffer has just been started so the new data must be passed to the AP and buffers must be swapped. This is accomplished as follows: INFLG is set to zero. Interrupts are enabled. IWAIT is called to wait until just after a D/A interrupt is processed. APPUT is called to transfer the new data to the AP. APGET is called to transfer the latest results from the AP. Finally the AP addresses of the new data and the result destination are transferred to the AP with a call to APPUT. Receipt of the second address by the AP starts the computations. Between each APPUT and APGET call are calls to APWD and IWAIT (see flowchart). This is to synchronize

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the starting of APPUT and APGET with the D/A interrupts. Because APPUT and APGET have interrupts disabled for a significant amount of time, a D/A interrupt could otherwise arrive at a time where it could be ignored for several hundred microseconds. Once the data transfer has been started by these two routines, it proceeds with interrupts enabled. There is sufficient time to process a D/A interrupt and go through APPUT and APGET before the next D/A interrupt occurs. After the APGET, SYFLG (sync flag) is checked. If non-zero the re-sync process is occurring, so the second APPUT is skipped to prevent timing problems within the AP program.

(10) (C) SYFLG is cleared. With the 512 words of beam data brought back from the AP is a 513th word which will be non-zero if there has been a speed conflict in the AP program (new data sent before old data processed). This is checked and if not zero, the program halts.

(11) (C) There are two tables of buffer addresses, one pointed to by BFPTR, the other by BFPT1. At this point these two are swapped. BFSET is called, which picks the individual addresses out of whichever table is specified by BFPTR and stores them in the proper places for use by BFIN, APPUT, DAIT, etc. Sense switch 1 is checked and if set, control is transferred back to the beginning of the program. SCTR is incremented and if non-zero (usual case) the program will wait for further interrupts. If SCTR is zero, as it will be every 3 minutes, BFHLT is called to stop Digital Controller input, SCTR is reinitialized to SLIM, and SYFLG is set non-zero (to bypass the second APPUT). Control is transferred back to (5), where the Digital Controller input is restarted. These last steps are known as the re-sync sequence.

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(C) It should be noted that during the collection of 2048 words of Digital Controller data group i, group i-1 is being sent to the AP and processed, group i-2 is being retrieved, and group i-3 is being sent to the D/A converters.

(C) Subroutine BFSET accomplishes the buffer switching required for double buffering. There are two tables, each containing buffer addresses in the 21MX and the AP-120. The buffers are switched by exchanging BFPTR and BFPT1. BFSET takes the table indicated by BFPTR and stores the addresses in individual locations as required by the routines which access these buffers. Some of these addresses will not be used immediately, but will be used after a certain event occurs. An example is IDABF, which will be stored in DAPTR on the first D/A interrupt following a Digital Controller DMA completion interrupt. DMA control word 2 (CW2) is computed from the input buffer address plus bit 15 and stored in location CW2 for use by BFIN.

(C) BFIN starts or continues the Digital Controller input. As explained under BFIT, this is a time-critical process, so many functions are accomplished elsewhere, such as the setting up of DMA control words and buffer switching. The functioning of BFIN is identical to BFIN in program Y0003. Additionally, before enabling interrupts, INFLG is set non-zero to trigger AP data transfers and switching of buffer addresses.

(C) BFHLT stops the input process by resetting the data enable bit on the Digital Controller. It also resets the interface and DMA. By resetting the data enable bit, it allows that bit to be set again by BFIN, thereby forcing resynchronizing of the input data.

(C) IWAIT provides a means of synchronizing with the D/A interrupts. First, INT is set to zero. When a D/A interrupt occurs, the processing by DAIT includes setting INT=1. Therefore IWAIT will loop until a D/A interrupt occurs, is processed, and control is returned to the point of interruption, at which point INT=1, and IWAIT continues by returning control to the caller.

(C) Subroutine TDBFI performs the operator interface, all computations performed in the 21MX, and the transmission of beamforming constants (BTABLE) and shading table (HTABLE) to the AP-120. TDBFI is described in the following paragraphs.

(12) (C) Pointers to the various arrays in the AP are computed. The location of these arrays is critical to the operating speed of the AP program because of memory interleave; in particular, which arrays start on even addresses and which start on odd addresses. There are a few unused addresses in main data memory, but this is required due to the odd-even requirements.

(13) (C) APCLR is called to initialize the AP software. The various AP data arrays are cleared/initialized as required. The one special initialization procedure required is the delay table (FSTAB), which requires zeros except in pointer locations, which require integer (fixed point) ones. This is accomplished by subroutine CDTAB. All other clearing is performed by calls to AP Library subroutine VCLR. BTABLE is cleared. It will have the appropriate constants stored in it later in the program as directed by the operator.

(14) (C) The array type ITYP (1-3) is input from the keyboard. Although not apparent from the flowchart, a range check is performed on this and other inputs by subroutine INPT. If array type is 2 (MF), the sample rate might be either 2 or 3 (MF or HF), so the sample rate (2-3) is input from the keyboard. Otherwise, sample rate ISR is set equal to array type.

(15) (C) KSYNC is looked up in a 3-entry table based on ISR. KSYNC is the number of 2048-word input buffers in 3 minutes, the resync interval. It is passed back to the caller (TDBFM) where it will be stored in SLIM. The synthesizer frequency required is computed by multiplying sample rate (looked up in table SRTAB according to index ISR) by 1.716, and printed.

(16) (C) Time Domain Beamforming uses TAP II shading table number 3. There are three of them, sorted on the "common track" ICOMO on sectors 3,6, and 9 for the LF, MF, and HF arrays (ITYP), respectively. The appropriate table is read into the first 64 words of HTABLE by subroutine DISC. Because of the output rescaling, this table is multiplied by 0.25 so that all inputs are prescaled to produce the correct output. These 64 words are moved throughout the 2048 words of HTABLE.

(17) (C) The maximum number of beams ever allowed is 16, however, if ISR=3 (HF), the maximum is 6, and IBMX is set to 16 or 6 to reflect the proper maximum. The beamforming constants are found in a 3-dimensional array, ZTABLE (I, J, K), where:

I=1 for B1, I=2 for B2, I=3 for delay indicator

J-1 is angle in degrees (0-90)

K is array type (1-3) or 4 for MF/HF case.

(C) IBIDX is used as the index K, above, and is now set to 1-4 according to ITYP and ISR. ZTABLE (for K=IBIDX and I=3) is searched for transition points. (ZTABLE(3,J,IBIDX) will be either a zero or one.) Indicators I5, I6, I7, I8 are set to the boundaries, in degrees, of the zones just found. Providing there is a transition point, I5 will always be 0 and I8 will always be 90. If there are no transition points, I5 through I8 are set to 0, 90, 91, and 91, respectively, I4, I3, I2, I1 are set to a (negative) mirror image of I5-I8, with the exception that I4=-1. Consequently, if the transition occurs between 34 and 35 degrees, I1-I8 will be set to -90, -35, -34, -1, 0, 34, 35, 90.

(18) (C) Instructions for operator entry of angles are printed. Angles must be entered in pairs and both items of a pair must lie within the boundaries specified by I1, I2 or I3, I4 or I5, I6 or I7, I8. As the angles are entered, this condition is checked. Input is terminated when IBMX angles have been entered or when 99 is entered. The BTABLE is filled as angles are entered. A mode indicator is stored in the first of each 5 BTABLE entries, B constants (from ZTABLE) for the first angle of a pair in the next two entries, and B constants for the second angle of a pair in the last two entries. Because the mode for both angles of a pair must be identical, only one mode indicator for each pair is necessary Mode is determined from ZTABLE (3,J,IBIDX), the sign of the angle, and a lookup table. When all angles have been entered, the number of beams, NBEAMS, is computed. This is the number of angles entered, rounded up to an even number. This number is passed back to the caller.

(19) (C) A summary of the entered and computed data is printed. This includes array type and sample rate, synthesizer setting, and the list of steer angles. An instruction as to what filters to select and the valid frequency range of the analog output is also printed. These numbers are determined by array type and sample rate.

(20) (C) BTABLE and HTABLE are transmitted to the AP. APWD and APWR are called to ensure that data transmission and operation of the last AP program (VCLR) are completed. APCLR is called to erase the program directory and reset the AP software. Finally, TDBF, the main AP beamforming program, is called. This starts TDBF's operation. Control is returned to the caller.

PROGRAM: (U) CLEAR DELAY TABLE, CDTAB

1. FUNCTION. (U) CDTAB is an AP-120 subroutine which initializes the delay storage table used by subroutine DELAY. All pointer locations are initialized to integer ones and all data locations are initialized to floating point zeros.

2. CONSTRAINTS. (U) None

3. CALLING SEQUENCE. (U) CALL CDTAB (A,N)

where A is base address of table

N is number of channels.

4. DESCRIPTION OF INPUT. (U) None

5. DESCRIPTION OF OUTPUT. (U) Output is the initialized delay table. The delay table is described in subroutine DELAY.

6. FILES USED. (U) None

7. ERRORS. (U) None

8. COMPUTER OPERATOR INSTRUCTIONS. (U) N/A

9. DESCRIPTION OF PROCESSING. (U) Due to the interleaved nature of AP-120 programs and the sequential nature of flowcharts, it is impossible to provide a flowchart for this program. The reader is referred to the program listing and the comments thereon for further information.

SUBROUTINE: (U) DELAY INPUT VALUES - DELAY

1. FUNCTION. (U) This routine delays a table of new data by various unit delays. The result is two delay tables, E and F. In table E, channel J will be delayed J-1 unit delays. In table F, channel J will be delayed N-J unit delays.

2. CONSTRAINTS. (U) None

3. CALLING SEQUENCE. (U)

0 = base address of new data

1 = base address of old data, forward

2 = base address of old data, reverse

3 = base address of output table, forward

4 = base address of output table, reverse

5 = number of channels "N"

JSR DELAY

4. DESCRIPTION OF INPUT. (C) Input is an array of N input values and the two delay storage tables. Each of the delay tables requires 2144 storage locations for N=64. The format of a delay table is: CDCDDCDDD, etc., where C is a counter and D is data. Counters are integers occupying only the mantissa of the floating point word. Data values are floating point.

5. DESCRIPTION OF OUTPUT. (U) Output is the delay tables (described above) and two delay data tables, each requiring N main data storage locations. These two tables are E and F, described above.

6. FILES USED. (U) None

7. ERRORS. (U) None

8. COMPUTER OPERATOR INSTRUCTIONS (or SUBROUTINE LIST). (U) N/A

9. DESCRIPTION OF PROCESSING. (U) Due to the interleaved nature of AP-120 programs and the sequential nature of the flowcharts, it is impossible to provide a flowchart for this program. After initialization and "intro" work, the main loop basically consists of fetching a counter, putting it in S-PAD (it is an integer) incrementing it, and comparing it with the channel number. If greater, it is reset to 1. The resulting counter is stored back in the original location. The new data is stored in the main data address corresponding to the previous content of the counter, and the content of the main data address indicated by the new counter is the delayed data and is stored in table E or F as appropriate. Operation then continues with the next channel.

(U) Tables C and D, the delay storage tables, are identical in format, except that in table C, channel 1 is at the low-address end and in table D, channel N is at the low-address end. In table D, although there are N spaces reserved for counters, they are not used. Because of the limited time available for DELAY, the counters from table C are always used. Table C must be initialized with integer ones in all counter locations prior to the first time DELAY is called.

(U) The reader is referred to the program listing and the comments thereon for further information.

SUBROUTINE: (U) VECTOR FLOAT AND MULTIPLY, VFMUL

1. FUNCTION. (U) VFMUL floats each element in vector A and multiplies the result by the corresponding element in vector B. The results are stored back in the same positions in vector A.

2. CONSTRAINTS. (U) None

3. CALLING SEQUENCE. (U)

   0=A, the array to be floated, also destination array

   1=B, the floating point multiplier array

   2=N, the element count

   JSR VFMUL

4. DESCRIPTION OF INPUT. (U) Input is an integer array and a floating point array.

5. DESCRIPTION OF OUTPUT. (U) Output is a floating point array. The integer array is destroyed.

6. FILES USED. (U) None

7. ERRORS. (U) None

8. COMPUTER OPERATOR INSTRUCTIONS. (U) N/A

9. DESCRIPTION OF PROCESSING. (U) Due to the interleaved nature of AP-120 programs and the sequential nature of flowcharts, it is impossible to provide a flowchart for this program. The floating is done by passing the integer through the floating adder and forcing an exponent of 27. This results in a normalized floating point number. This is the algorithm used in the AP Library subroutine VFLT. The reader is referred to the program listing and the comments thereon for further information.

PROGRAM: (C) TIME DOMAIN BEAMFORMER, TDBF

1. FUNCTION. (C) TDBF forms up to 16 beams from time domain data.

2. CONSTRAINTS. (C) Maximum number of beams is dependent on input data rate. Number of input channels is fixed at 64.

3. CALLING SEQUENCE. (U) (from 21MX) CALL TDBF.

4. DESCRIPTION OF INPUT. (C) Input is an unlimited number of 2048-word arrays each containing 32 sets of 64 channels of sampled data. The BTABLE and HTABLE must be in main data before calling TDBF and the input data array must not be sent until TDBF has had a chance to reach its waiting point.

5. DESCRIPTION OF OUTPUT. (C) Output is an unlimited number of 513-word arrays each containing 32 sets of 16 beams, plus an error indicator in word 513 which will be non-zero if data was received before ready.

6. FILES USED. (U) None

7. ERRORS. (U) None

8. SUBROUTINE LIST. (U) Subroutines called: VFMUL, DELAY, TWOB, TWOBR.

9. DESCRIPTION OF PROCESSING. (U) Due to the interleaved nature of AP-120 programs and the sequential nature of flowcharts, it is impossible to provide a flowchart which accurately portrays the operations performed by this program. However, because this is basically a control program, a flowchart has been prepared which roughly shows the decisions and execution paths involved. Processing steps are keyed to the flowchart, Figure A-2.

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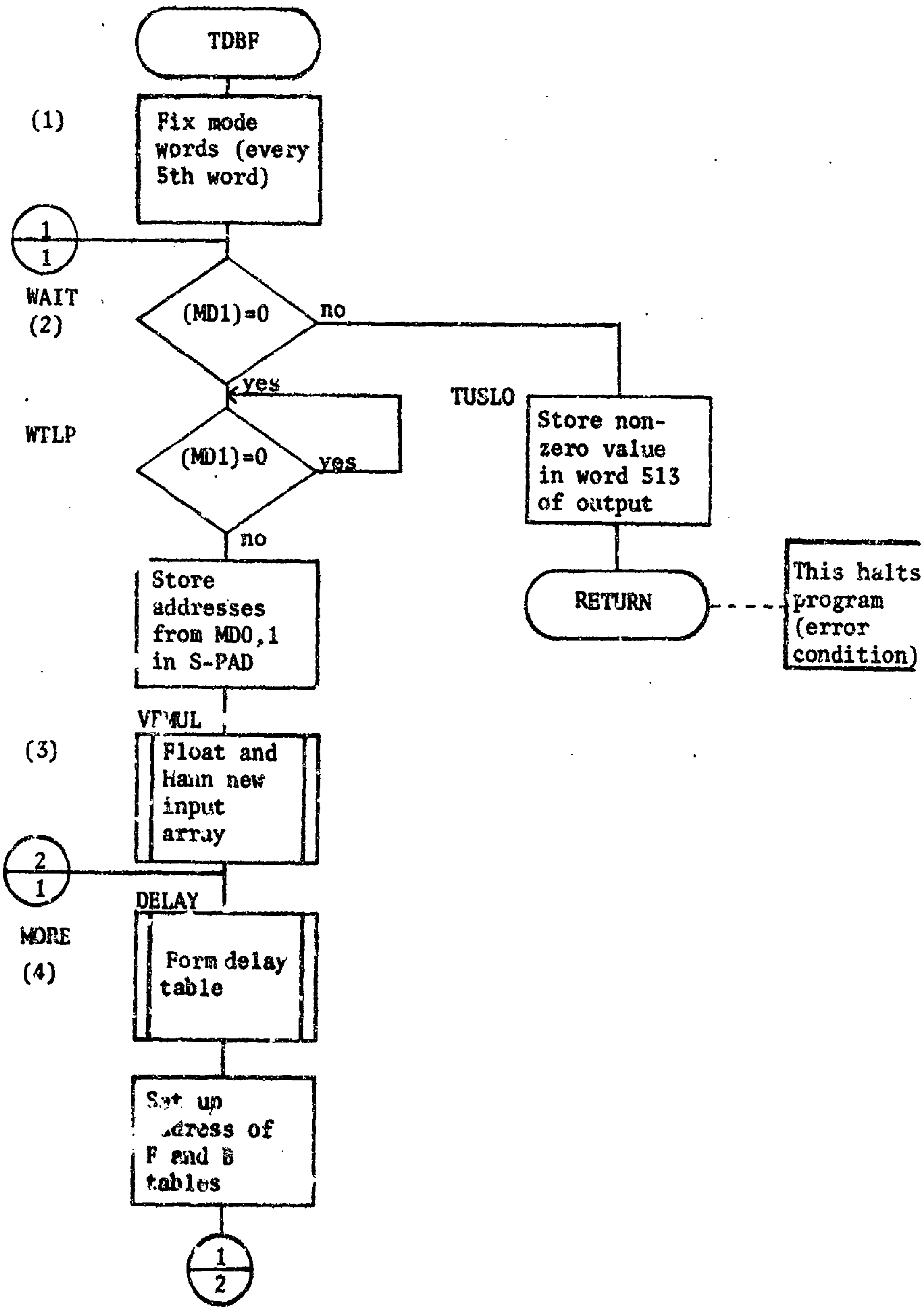

Figure A-2. TBDF (Sheet 1 of 2)

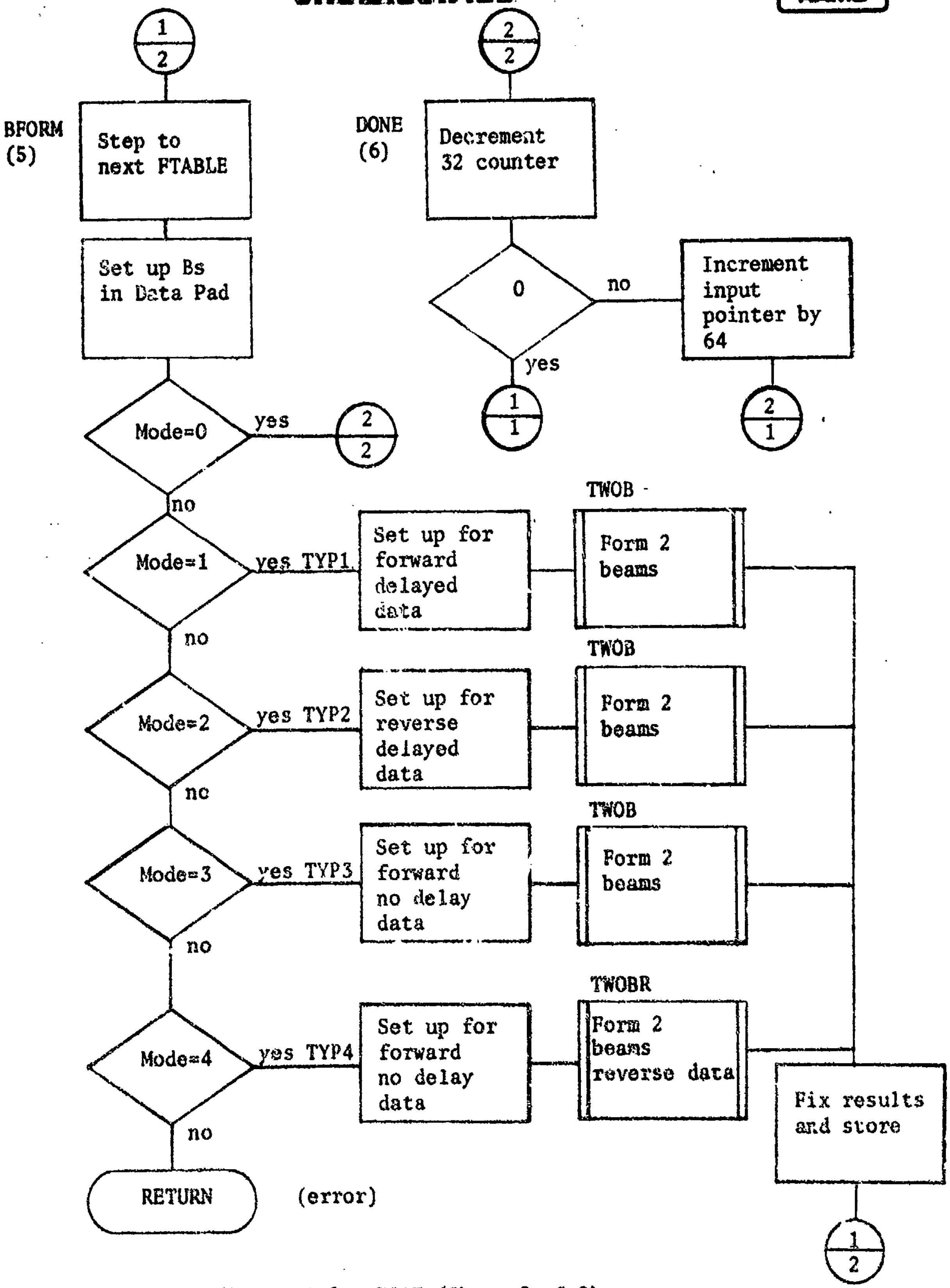

Figure A-2. TBDF (Sheet 2 of 2)

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(1) (U) Basically, TDBF fixes the mode indicators which accompany the B constants in the B table, then waits until new input data is present. The fixing of the mode words is performed only once.

(2) (C) New data present is detected by a non-zero word present in main data word 1. If this word is already non-zero, the 21MX is sending data faster than the AP can process it, so an error bit is stored in word 513 of the output buffer and a RETURN is executed. This halts the AP. Otherwise, the AP program never stops. Once data is present, the program continues. This word (main data 1) is the address for beam data output and is saved in S-PAD for this use. Main data word 0 is the input data buffer address (where the 21MX has placed the data to be worked on now). This is also saved in S-PAD. Addresses are passed rather than being built in so that the data and processing can be double-buffered.

(3) (C) VFMUL is called to float the data and apply the shading table to it.

(4) (C) DELAY is called to delay the input data.

(5) (C) Various initialization required prior to calling TWOB or TWOBR is performed, interleaved with checking the current mode word. If mode is zero, all beams for this 64-word buffer have been formed, and control is transferred to (6). Otherwise, the mode word determines whether forward or reverse data is to be used. TWOB is called to form two beams, unless reverse, undelayed data is called for (Mode 4). In this case, because there is no table of reverse, undelayed data, TWOBR is called, because it accesses the input table directly, but from the high-address end. The results,

in Data Pad, are stored in the output buffer. Control returns to the beginning of this step (5) to process the next two beams. This looping will continue until mode is zero.

(6) (C) Here, a zero mode word has been encountered. (A zero in the mode position terminates the BTABLE.) A counter, which was initialized to 32 when new data was received, is decremented. If zero, all 2048 words have been processed, so the program goes back to the point where new data is awaited. Otherwise, the input pointer is moved up to the beginning of the next 64 words and control is transferred back to (4), where B table and F table pointers will be moved back to the beginnings of the tables and a full new set of beams will be formed.

(U) TDBF must always be waiting for the 21MX, as the speed of the input data is fixed by the sample rate. To have the 21MX wait for the AP would mean that input data was accumulating faster than it could be processed, a situation which cannot continue indefinitely.

(U) The flowchart and this description are a vastly simplified, sometimes re-ordered account of the TDBF program. For information on the actual operation of the program, the reader is referred to the program listing and the comments contained thereon.

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SUBROUTINE: (C) TWO BEAM BEAMFORMER, TWOB

1. FUNCTION. (C) TWOB forms two beams from a table of channel data (either from DELAY or undelayed) and two pairs of B constants, which define the steer angles.

2. CONSTRAINTS. (C) TWOB is set up for 64 channels of input data.

3. CALLING SEQUENCE. (C)

DPY(0) B1 beam 1

DPX(0) B2 beam 1

DPY(1) B1 beam 2

DPX(1) B2 beam 2

0=A = base address of input data array

1=F = base address of F table

JSR TWOB

4. DESCRIPTION OF INPUT. (C) Input is 64 channels of sampled data, delayed or undelayed as required, in forward or reverse order as required, and the F table, which is a unit delay table which is the output of the previous pass of TWOB for these same two beams.

5. DESCRIPTION OF OUTPUT. (C) Output is the beam values in DPY(-2) and DPY(-1) for beams 1 and 2, respectively. Output also is the F table, described under INPUT.

6. FILES USED. (U) None

7. ERRORS. (U) None

8. COMPUTER OPERATOR INSTRUCTIONS. (U) N/A

9. DESCRIPTION OF PROCESSING. (C) Due to the interleaved nature of AP-120 programs and the sequential nature of flowcharts, it is impossible to provide a flowchart for this program. Basically, TWOB performs the operations described in Figure A-3, Time Domain Beamforming Topology. In this figure, a Φ1 operation is two of the diagrams shown at the bottom of the illustration. This may be reduced to the following equations, shown as Fortran statements, solved in order:

```
OUT1=F1-B1*(F1+IN)

F1=IN+B1*(F1+IN)

OUT2=F2-B2*(F2+OUT1)

F2=OUT1+B2*(F2+OUT1)
```

(C) OUT2 is the final output of the Φ1 operation. The F's are unit delays. There are 63 F1's and 63 F2's for each beam, or 252 entries in the F table for each pair of beams (this is for 64 channels). A Φ2 is a unit delay, accomplsihed by the DELAY subroutine, before calling TWOB. Also the Φ2 delays may be null delays for certain ranges of steer angle.

(U) The meaning of a unit delay is that a given value is stored on this pass through TWOB, and retrieved on the next pass through TWOB, one sample interval later. A 4Φ2 is a delay of 4 sample intervals, or 4 passes through TWOB.

(U) In the actual AP program, the main processing loop contains some peculiarities. One of these is that the loop does not start at the beginning of the calculation. This was required because of the dependence of some calculations on previous results and the existence of certain op-code field conflicts at the end of the loop. Also, the method of branching back to the beginning of the loop had

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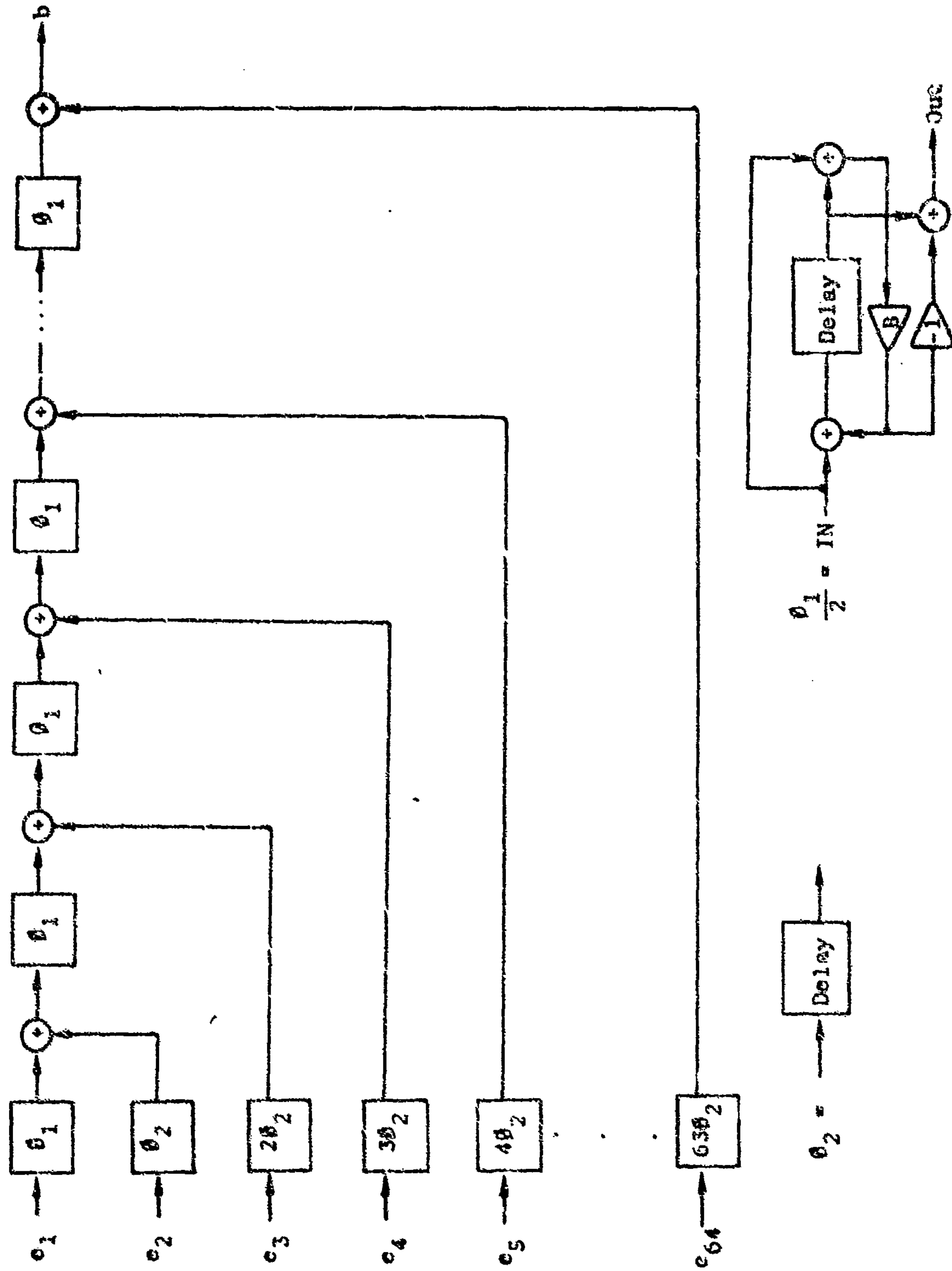

Figure A-3. Time Domain Beamforming Topology

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to be done in a rather unorthodox manner because the loop was longer than 16 instructions.

(U) Figure A-4 shows the actual operations performed in each instruction, and is essential for understanding the program. The numbers in the left-hand column represent the program step shown in the comment on the listing. The source statements are divided into columns identical to those on the illustration. The first two columns are the odd and even beam arithmetic, respectively, and the third column is memory access, loop counting, and branching.

(U) Numerous comments throughout the assembly listing provide further information and the reader will receive abundant enlightenment by directing his attention there.

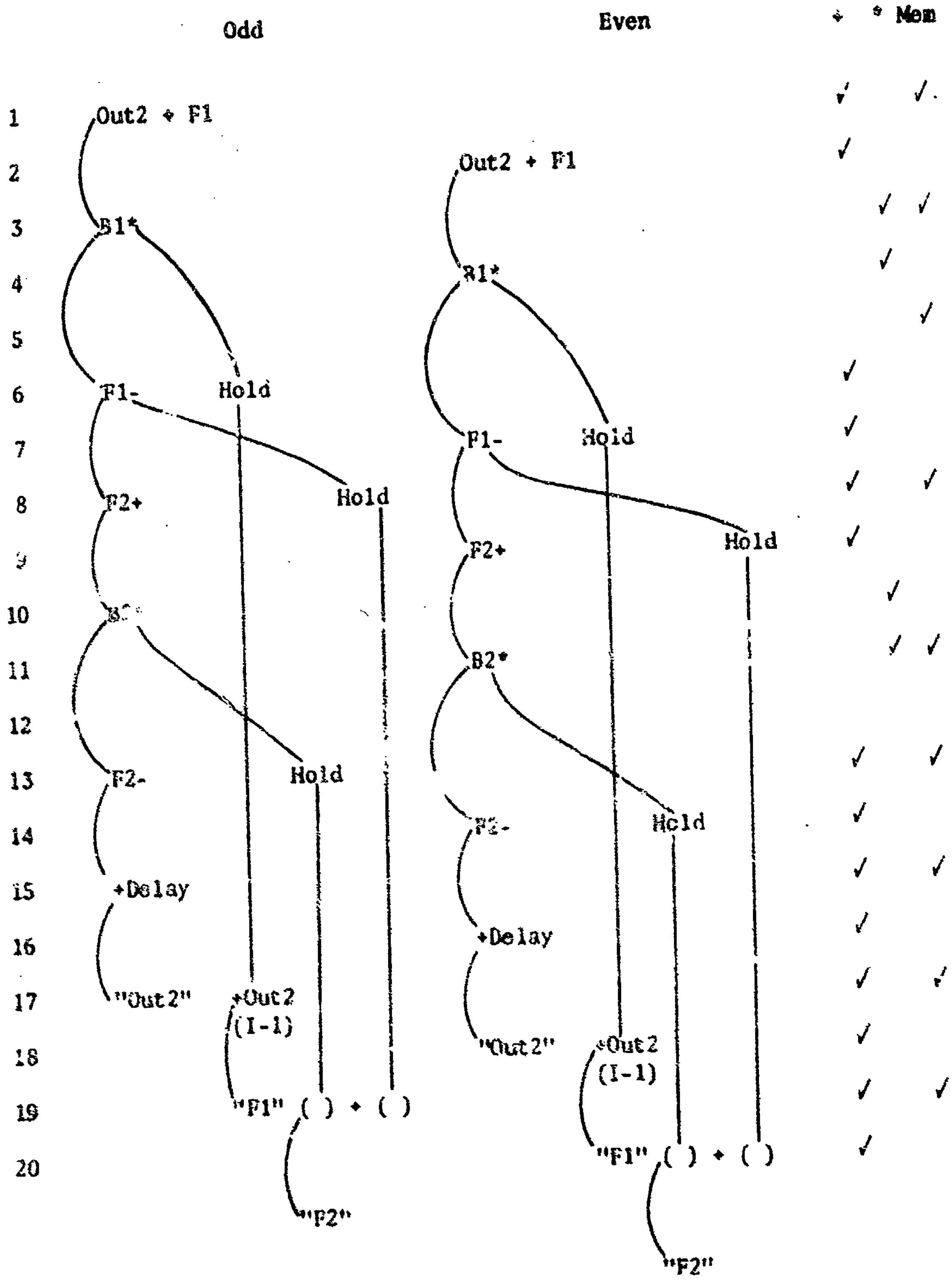

Figure A-4. TWOB Process Sequence Diagram

SUBROUTINE: (U) TWO BEAM BEAMFORMER, REVERSE, TWOBR

1. FUNCTION. (U) TWOBR is identical to TWOB except that it accesses the input data from the high-address end.

2. CONSTRAINTS. (U) See TWOB

3. CALLING SEQUENCE. (U) See TWOB

4. DESCRIPTION OF INPUT. (U) See TWOB

5. DESCRIPTION OF OUTPUT. (U) See TWOB

6. FILES USED. (U) None

7. ERRORS. (U) None

8. COMPUTER OPERATOR INSTRUCTIONS. (U) N/A

9. DESCRIPTION OF PROCESSING. (U) See TWOB

(U) MODIFICATIONS TO TIME DOMAIN BEAMFORMING PROGRAM

(C) A change has been made to the Time Domain Beamforming Program which allows operation of the LF array at the MF sample rate.

(C) The impact on the preceding text and flowcharts is minimal. Not described there are the facts that there are now five tables of beamforming constants instead of four, and that there is a question to the operator as to which sample rate is desired when the LF array is specified.

APPENDIX B

TAP-II TAPE FORMATS

IBM TAPE FORMATS

B.1 GENERAL FORMATS

(C) Two types of tape records are written by TAP-II: records containing either the Accumlation Table data or the complex coefficients data. Both types contain a 4480 integer word block written in one record. The record type is determined by the contents of Word 100. If Word 100 = 1, the record contains complex coefficient data; if 2, the record contains Accumulation Table data.

(C) To read the data, it is suggested that the tape read statement input the entire record into an array, IBUF, dimensioned to 4480. If the dimension and equivalence statements shown in Figure B.1-1 are employed, the information contained in the record is conveniently accessible. In both Figure B.1-1 and the following Figure B.1-2, FORTRAN data type conventions are followed, with the first letter defining whether the variable is integer or floating point.

(C) The first 128 words in both types of records contain header information. Figure B.1-2 summarizes the information useful to a program reading the tapes. Variable names used make use of the equivalence conventions given in Figure B.1-1.

(C) The second 128 words in either type of 4480-word record contains nonacoustic data. This data is identical in format to the form in which it was originally received from the batch computer. This format will be defined by Systems Integrated software, and is not included here.

B.2 COMPLEX COEFFICIENTS

(C) If the contents of IHDR (the 100th word of the input record) equals 1, the record contains 2048 words of complex coefficient data, in floating point, which will be in array FDAT using the conventions of Figure B.1-1.

```
DIMENSION      IBUF(4480)
DIMENSION      ICOM(128), INADAT(128), IDAT(4096), FDAT (2048)
DIMENSION      IDATE(6), SR(3), LGRP(8), ITIM(3), SP(3)

EQUIVALENCE    (ICOM(1),IBUF(1)), (INADAT(1),IBUF(129)),
               (IDAT(1),IBUF(257)
EQUIVALENCE    (NSAMP(1),ICOM(1)), (IDATE(1),ICOM(6)), (NINT,ICOM(39))
EQUIVALENCE    (KK,ICOM(3)), (BW,ICOM(15)), (SR(1),ICOM(27))
EQUIVALENCE    (ITYP,ICOM(33)), (ISHD,ICOM(34)), (IW,ICOM(35))
EQUIVALENCE    (IAV,ICOM(36)), (AUTM,ICOM(37)), (NGRPS,ICOM(40))
EQUIVALENCE    (LGRP(1) ICOM(41)), (IHDR,ICOM(100)), (ITIM(1),ICOM(61))
EQUIVALENCE    (JJ1,ICOM(101)), (KHALF,ICOM(102)),(KCC,ICOM(103))
EQUIVALENCE    (SP(1),ICOM(51)), (SVEL,ICOM(83)), (FDAT, IBUF (257)
```

Figure B.1-1. Dimension and Equivalence Conventions

BUNKER RAMO

INFORMATION	LOCATION
1. Length of tape	All records are 4480 words long, with 16-bit integer words
2. Type of tape record	Defined by IHDR: 1 = Complex Coefficients 2 = Accumulation Table (averaged powers)
3. Date	Contained in Array IDATE. IDATE is a 6-element integer array containing ASCII information in a 6 A2 format
4. Time	Contained in array ITIM: ITIM(1) = hours (integer format) ITIM(2) = minutes (integer format) ITIM(3) = seconds (integer format) The time is that read from the time code generator at the start of a TAP II analysis. Time is read only once per analysis, so several succeeding records might have identical time headers.
6. Number of Averaging Intervals in current TAP II Analysis	Defined in NINT
7. Current value of Averaging Loop Counter	Defined in KK
8. Number of 128-point frequency line groups being analyzed	Defined in NGRPS

Figure B.1-2. Header Information (Sheet 1 of 3)

BUNKER RAMO

INFORMATION	LOCATION
9. Lambda Array Type	Defined in ITYP: 1 = LF 2 = MF 3 = HF
10. Hydrophone Channel Sample rate	Defined in SR (ITYP). Units are Hz
11. Time-Frequency Transform length	Defined in NSAMP. Will be either 1024, 2048 or 4096
12. FFT frequency line spacing	Defined in BW. BW = SR(ITYP)/NSAMP
13. Type of Time Weighting Window	Defined in IW. 1 = Rectangular 2 = Hanning
14. Array Shading Table	Defined in ISHD (will be 1, 2, or 3). Consult logs to find out what type of shading was put into shading table ISHD
15. Type of averaging	Defined in IAV (1 = simple, 2 = exponential). This affects the power data being stored in the Accumulation Table. For simple averaging, the new powers computed in each averaging cycle are simply summed to the table (the table is cleared at the start of every new analysis). Then at the completion of the last averaging cycle the table is divided by NINT. For exponential

Figure B.1-2. Header Information (Sheet 2 of 3)

INFORMATION	LOCATION
	averaging, each newly computed power is summed to the current table contents using the formula: New Table Value = New Sample + $e^{-t/AVTM}$ (old table value - new sample)
16. Exponential Averaging Time	Defined in AVTM. Units are seconds.
17. Time to collect the data sample for one average	Calculated using the formula: t = NSAMP/SR(ITYP)
18. The frequency of the first FFT line in a tape record of IHDR Type 1 (complex coefficients)	Calculated using the formula: F = BW* (128.*(LGRP(JJ1)-1.) + 64.*KHALF + 16.*KCC)
19. The frequency of the first FFT line in a tape record of IHDR Type 2 (powers in Accumulation Table)	Calculated using the formula: F = BW* (128.*(LGRP(JJ1)-1.) + 64.*KHALF)
20. Lambda array element-element spacing	Defined in SP(ITYP). Units are meters.
21. Sound velocity	Defined in SVEL. Units are meters/sec.

Figure B.1-2. Header Information (Sheet 3 of 3)

(C) Each consecutive 128-word section of IDAT contains 64 complex numbers, in normal form, representing the beamformer output vs steer angle for one frequency cell. A total of 16 frequency cells are included in any one record. The frequency of the first cell is given by the equation listed in line 18 of Figure B.1-2. The succeeding frequencies follow in order, spaced in increments of BW Hz.

(C) Both the real and imaginary parts of the complex numbers are in rms voltage units. The maximum rms voltage for any hydrophone is 7.07, consequently the maximum array output is 64 (7.07) = 452.55 volts (rms).

(C) The complex numbers (an intermediate output of TAP II) are the direct results of the second FFT. The steer angles representing the 64 complex results are functions of frequency. These steer angles are given by the relation:

$$\theta_r = \sin^{-1}\left[-r/32.*(F/FM)\right]$$

where r = an index varying between -31 to +32

F = The frequency of the FFT line

FM = The array aliasing frequency (= SVEL/(2.*SP(ITYP))

In each group of 64 complex numbers (128 consecutive elements of array IDAT), the numbers are stored in order of r = 0 to +32, then -31 to -1.

B.3 ACCUMULATION TABLE

(C) If the contents of IHDR (the 100th word of the input record) equal 2, the record contains 4096 words of Accumulation Table data, which will be stored in array IDAT if using the conventions of Figure B.1-2.

(C) The Accumulation Table contains array output power as a function of frequency and steer angle. Each consecutive 64-word section of IDAT contains the power for 64 separate directions at one frequency line.

The frequency of the first line is given by the equation listed in line 19 of Figure B.1-2. The succeeding frequencies follow in order in increments of BW Hz. One record contains a maximum of 64 frequencies.

(C) The powers are in scaled voltage squared units. The scale factor is the same for all 4096 IDAT values, and is contained in IBUF (4353). The correct value in volts squared (rms) can be obtained by dividing the table values by 2** (15-IBUF(4353)).

(C) The Lambda array aliasing frequency is given by:

FM = SVEL/(2.*SP(ITYP)) (See Figure B.1-2.)

(C) If the FFT line frequency is below this aliasing frequency, the 64 steer angles are the 64 TAP II steer angles, shown in Figure B.3-1. The data is in the same order, the first value in a group of 64 numbers representing the most rearward steer angle (-75.47°), and the last number the most forward (+90°).

(C) If the FFT line frequency is above the array aliasing frequency, the steer angles are not standard. In this case the steer angles are given by the relation:

$$\theta = \sin^{-1}\left[r/32(F/FM)\right]$$

where F = FFT line frequency

FM = array aliasing frequency

r = index varying between -31 and +32

The order of storing r in the Accumulation Table starts at -31 and increments upwards to 32, for 64 total angles per frequency line.

1: -75.47	2: -69.55	3: -64.96	4: -61.04
5: -57.46	6: -54.29	7: -51.35	8: -48.59
9: -45.89	10: -43.39	11: -41.00	12: -38.68
13: -36.37	14: -34.19	15: -32.07	16: -30.00
17: -27.90	18: -25.91	19: -23.95	20: -22.02
21: -20.06	22: -18.18	23: -16.32	24: -14.48
25: -12.59	26: -10.78	27: -8.97	28: -7.18
29: -5.34	30: -3.55	31: -1.78	32: .00
33: 1.78	34: 3.55	35: 5.34	36: 7.18
37: 8.97	38: 10.78	39: 12.59	40: 14.48
41: 16.32	42: 18.18	43: 20.06	44: 22.02
45: 23.95	46: 25.91	47: 27.90	48: 30.00
49: 32.07	50: 34.19	51: 36.37	52: 38.68
53: 41.00	54: 43.39	55: 45.89	56: 48.59
57: 51.35	58: 54.29	59: 57.46	60: 61.04
61: 64.96	62: 69.55	63: 75.47	64: 90.00

Figure B.3-1. TAP II Standard Steer Angles (Degrees)

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SAI-78-527-WA	Spofford, C. W.	NELANT DATA ASSESSMENT APPENDIX III-MODELING REPORT	Science Applications, Inc.	770225	ND ADA 047680	U
PSI TR 036049	Barnes, A. E., et al.	OCEAN ROUTE ENVELOPES	Planning Systems Inc.	770419	ND	U
Unavailable	Unavailable	TAP II BEAMFORMING SYSTEM SOFTWARE FINAL REPORT	Bunker-Ramo Corp. Electronic Systems Division	770501	ADC011789	U
S01037C8	Unavailable	TAP 2 PROCESSING SYSTEM FINAL REPORT HARDWARE DOCUMENTATION (U)	Bunker-Ramo Corp. Electronic Systems Division	770501	ADC011790; NS; ND	U
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SAI78696WA	Unavailable ADA 05728	REVIEW OF MODELS OF BEAM-NOISE STATISTICS (U)	Science Applications Inc.	771101	NS; ND	U
TRACORT77RV109C	Unavailable	FINAL REPORT FOR CONTRACT N00014-76-C-0066 (U)	Tracor Sciences and Systems	771130	ADC012607; NS; ND	U
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TR052085	Solomon, L. P., et al.	HISTORICAL TEMPORAL SHIPPING (U) ADB 037100	Planning Systems Inc.	780628	NS; ND	U